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ORIGINAL ARTICLE

Effects of face-to-face and online yoga instruction on anxiety and flexibility

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ABSTRACT

A research study employing a non-equivalent pretest-posttest comparison group design was used to measure online and face-to-face (FTF) yoga instructional methods and their effects on anxiety, increased flexibility, and perceived behavioural intentions to practice yoga in the future. This study was conducted to discover if online yoga course instruction was just as effective as or more so than a course taught FTF. Findings suggest that online yoga instruction was significantly more effective in reducing the state anxiety of the students. However, there was no significant difference between groups on trait anxiety indicating that either method was equally effective. In contrast, the F2F course was significantly more effective in reducing the appearance anxiety of students when compared to the online yoga course. Students in FTF and online increased in flexibility with no significant difference between groups. Based on these results, online yoga can reduce certain types of anxiety and be just as effective at increasing flexibility. The findings show that online yoga can be just as effective as and sometimes more effective than FTF yoga in some aspects important for maintenance of health and wellness in individuals.
Keywords: Physical education, Video-based teaching, Physical exercise, Anxiety, Flexibility.

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INTRODUCTION

Yoga as a form of exercise has been found to prevent a variety of health problems and produce effects that helps individuals improve or maintain good health. In older adults, yoga has been found to strengthen balance (Jeter et al., 2014, Youkhana et al., 2016); aid in stroke rehabilitation (Lawrence et al., 2016); improve proprioception and balance function in individuals who have fallen (Wooten et al., 2018), and improve mobility, postural control, and gait speed (Kelley et al., 2014). Research has also shown improvements in a wide variety of health conditions when individuals practice yoga. Individuals with asthmas have had their quality of life and symptoms improved (Yang et al. 2016), patients with Parkinsen's disease have decreased lower back pain (Myers et al. 2020), and patients receiving chemotherapy and radiation and cancer survivors who practice yoga experience less sleep disruption, cancer-related fatigue, cognitive impairment, psychosocial distress, and fewer musculoskeletal symptoms (Lin et al. 2018). Yoga has been successful in helping those with depression, anxiety and PTSD (Meister and Becker 2018), relieving work-related stress among health workers (Maddux et al. 2018), and losing significantly more subcutaneous fat in obese women (Araneta et al. 2013). Other researchers (Amin and Goodman, 2014; Skowronek, Handler, and Mounsey 2014) found that yoga increased flexibility and decreased anxiety in their subjects.

Other research indicates that yoga can have preventative effects on a variety of conditions including diastolic blood pressure, HDL cholesterol and triglycerides, and uncertain effects on LDL cholesterol (Hartley et al. 2014); eating disorders (Borden and Cooke-Cottone 2020), and pulmonary function (Abel et al. 2013). Stahl et al. (2015) conducted a study of 4,000 patients from 2006-2014 whose doctors recommended treatment through mind-body techniques (e.g., Tai Chi, meditation, and yoga). These patients were compared to 13,000 patients whose doctors did not recommend mind/body techniques. Researchers were curious to see what effects the mind-body techniques would have on reducing healthcare use and costs. According to Stahl et al., "*Mind body medicine interventions are inexpensive relative to the cost of an emergency room visit, a hospitalization or even other complementary and alternative medicine (CAM) therapies... the cost savings from reduced emergency room visits alone in the treatment group relative to the control group, is on the order of $2360/patient/year*" (2015, p. 11).

Even though there is much research documenting the health benefits of yoga, there are factors that make people reluctant to practice yoga or to practice yoga more frequently including the cost of enrolling in a yoga course and the intimidation or embarrassment especially for individuals who are out of shape, overweight, or inflexible (Brems et al. 2015). Obesity as a result of poor eating habits and lack of exercise has raised concerns both in terms of individual health and public health. Healthcare costs have significantly increased as a larger numbers of Americans have become obese (Biener, Cawley, and Meyerhoefer 2017). According to Yashi (2022), almost 1 in 3 American college students were obese and that in 2021, 44% of college students in the US described their weight as either overweight or obese. She suggested that more physical activities such as yoga might help with this problem.

Other adverse health conditions related to a lack of exercise include reduced physical flexibility and increased psychological anxiety. Moreover, as individuals age and remain inflexible, they suffer from problems related to hip-joint mobility as well as lumbar spine degeneration. These conditions can cause pain, debilitation, and muscle weakness, and they also can contribute to falls among seniors (Iwamot et al. 2009), one-third of which lead to death within a year (Liu et al., 2015). Spruyt (2016) reported that anxiety is linked to heart disease, depression, gastrointestinal problems, headaches, and irritability. Hood (2015) estimated that more than 40 million people suffer from some form of anxiety, making it an equally troubling and significant health problem alongside obesity.

There are relatively few studies on the effects of yoga in adolescents or college students. However, one study found that yoga nidra helped to alleviate the life stress intensity level and increase the self-esteem in university students (Dol 2019). Gaskins et al. (2014) also found that yoga practice is associated with improvements in affect and stress in a young-adult college population. Similarly, college students experienced a reduction in stress and anxiety levels after completing a six-week yoga and meditation program before taking final examinations (Lemay and Buchanan, 2019). Also, Ju et al. (2019) found that yoga interventions were effective in reducing anxiety, depression, stress and heart rate among 763 college students who practiced yoga for just eight weeks. Likewise, He et al. (2018) found that just a single yoga session lasting 90 minutes among the college-aged population increased positive moods and decreased stress levels. Finally, LaSala et al. (2021) found that yoga increased flexibility in college students.

As a result of the COVID 19 pandemic, many places that once offered F2F yoga classes were shuttered. During this time, online yoga was a growing phenomenon used to offer continued practice to individuals during the pandemic. Brosnan et al. (2021) conducted a study during the pandemic that demonstrated online yoga classes were an acceptable alternative to F2F yoga across eight different studies. Arruda et al. (2018) found that a combination of F2F instructor-led yoga along with video-based yoga was an effective therapy for adolescents with inflammatory bowel disease. Patients reported reduced stress and improved ability to identify and manage physical symptoms. As these studies demonstrate, online yoga is becoming more mainstream and acceptable. Online yoga may offer a promising alternative to face-to-face (F2F) yoga that is more convenient, accessible, and accommodating for individuals with different needs. As a result of growth in online yoga offerings, related research has been on the rise. (Brosnan, Nauphal and Tompson, 2021). Particularly, as a consequence of COVID-19 there has been a growth in daily online yoga sessions offered on social media, which apparently prove useful in providing a feasible and accessible means of achieving mental as well as physical well-being (Sharma et al. 2020). According to Brosnan et al., this fairly new approach to delivering yoga will allow providers to include online yoga as a lower-cost, non-invasive intervention for a wide variety of physical and mental health disorders and allow individuals to practice yoga in the comfort of their homes with ease and security. Online yoga has the potential to reach a wider and more diverse audience, reduce the amount of poor health conditions and decrease the cost of healthcare.

MATERIAL AND METHODS

A quasi-experimental research study was conducted at a midsize Midwestern university in the United States to examine if there is a difference between face-to-face and online yoga on college students' anxiety (strait-trait and appearance), flexibility, and intentions to practice yoga long term. This research study used quantitative methods and a nonequivalent group design. A pretest-posttest comparison group design was used to compare the pre-intervention results and the post-intervention results of (a) a traditional F2F yoga course (comparison group) and (b) an online yoga course (treatment group). Research questions included the following:

RQ1: Is there a statistically significant difference between a face-to-face yoga course and an online yoga course in students' scores on the State-Trait Anxiety Inventory and the Appearance Anxiety Inventory Test?

RQ2: Is there a statistically significant difference between a face-to-face yoga course and an online yoga course in students' scores on the sit-and-reach test?

RQ3: Is there a statistically significant difference between a face-to-face yoga course and an online yoga course in student behavioural intensions towards yoga?

RQ4: Is there a statistically significant difference within the face-to-face yoga course and the online yoga course in students' scores on the pre/post State-Trait Anxiety Inventory, Appearance Anxiety Inventory test, and flexibility scores on the sit-and-reach test?

Participants

Participants consisted of traditional college students ranging from 18 to 23 years of age but based on typical yoga class enrolments with 50 students enrolled in a F2F yoga class and 50 students enrolled in an online yoga class. This convenient sample was selected because both classes were taught by one of the authors at a Midwestern university. A non-random, convenience but purposeful sampling method was used to select participants. Participants were students who signed up for the online yoga class and the F2F yoga class, which was already offered at the university. The overall sample consisted of both males (*n* = 38, 42%) and females (*n* = 52, 58%).

In the online course there were 17 males (37%) and 28 females (62%). The F2F course, consisted of males (n = 21, 46%) and females *(n* = 24*,* 53%). The majority of online participants were between 18 and 26 years of age and the sample included participants of a variety of races including Caucasian (*n* = 28, 62%), African American (*n* = 10, 22%), Asian (*n* = 2, 4%), and other *(n* = 3, 7%). The F2F class had a racial makeup of Caucasian (*n* = 35, 78%) and African American (*n* = 10, 22%). The total racial make-up was as follows: Caucasian (*n* = 63, 70%), African American (*n* = 20, 22%), Asian *(n* = 2, 4%), and other *(n* = 3, 7%). About half of all online participants indicated they were active in some type of sports activity including basketball (*n* = 6, 13%) football *(n* = 3, 7%), baseball (*n* = 2, 4%), track (3, 7%), volleyball (*n* = 2, 4%, and soccer (*n* = 1, 2%).

In the F2F course, students participated in basketball *(n* = 1, 2%) football (*n* = 15, 33%), baseball (*n* = 2, 4%), track (0, 0%), volleyball (*n* = 2, 4%, soccer *(n* = 1, 2%), and swimming (*n* = 1, 2%), revealing additional evidence that the BMI in the F2F is skewed due to the larger number of football players. The average height of the online group was 5'7", and the average weight was 161 pounds making the average BMI for the online students 25.2, a BMI which is considered overweight. The students in the F2F course had an average height of 5'8" with an average weight of 175 pounds, making the BMI for this course 26.6 which is also considered as technically overweight.

Measures

Four self-report instruments were used to measure flexibility, anxiety, and perceived behavioural intentions. An additional questionnaire was used to collect information about the participants including demographics, physical characteristics (e.g., height, BMI) and exercise histories. The flexibility component was measured using the ruler-based, self-administered *sit-and-reach (SR) flexibility test*. The SR test was conducted twice by all members of both groups and was conducted once at the beginning and once at the end of the course by members of both the online and the F2F groups. The ruler-based, self-administered version of the SR required students to sit with a yardstick parallel to the ground between their legs, with the 40-cm mark aligned with the ankle. Students then reached as far past the 40-cm mark as they could. Students recorded their SR data in centimetres in negative units short of 40 cm or positive units beyond 40 cm. To help ensure accuracy and consistency in the measurement process, an in-class demonstration from the instructor was provided for F2F students, and an instructional video was made available to the students participating online. The SR flexibility test is used by the American College of Sports Medicine to measure the flexibility levels of hamstrings and is considered a safe, practical, and moderately accurate field test for flexibility (Baltaci et al. 2003).

The anxiety level of participants was measured using the *State-Trait Anxiety Inventory (STAI).* The STAI was administered before and after both the online yoga course (i.e., the treatment group) and the F2F yoga course (i.e., the control group). The STAI consisted of 40 items that each feature a 4-point Likert-type response scale: 20 questions to measure state anxiety, which is a type of anxiety that is felt at the present moment in time; and 20 questions to measure trait anxiety, which is a type of anxiety that describes a person's tendency to become anxious. The STAI questionnaire items measured participants' overall anxiety levels, state and trait; and the higher the score on the STAI, the higher the level of anxiety (Ping et al., 2008).

Additionally, body image anxiety was also measured both pre-yoga intervention and post-yoga intervention (within both delivery methods) using the *Appearance Anxiety Inventory Test (AAIT).* The Appearance Anxiety Inventory Test is a valid instrument used to measure the degree to which individuals experience anxiety related to poor body image. The AAIT consists of 10 items and uses a 4-point Likert-type response scale. The questionnaire items measure overall anxiety levels that individuals may be experiencing related to their appearance. The higher the AAIT score, the higher the level of anxiety.

At the end of the six-week class, the researcher administered a *behavioural intentions questionnaire* to identify the extent to which participants plan to continue practicing yoga exercises, meditation techniques, and breathing techniques they learned in the class. The researcher-designed questionnaire consisted of seven items that feature a seven-point Likert-type scale. These items explore the extent to which participants agree with statements about their intentions to change their behaviours related to practicing the elements of yoga on a regular basis as a result of the course.

The *Personal Information Questionnaire* allowed the researcher to compare groups based on variables such as age, gender, BMI, and athletic involvement to determine whether differences existed among the two groups in the areas of flexibility, anxiety, and behavioural intentions.

Procedures

One of the authors, who taught both sections of the yoga course, had 18 years of experience teaching yoga. She had over 200 hours of yoga training and held a Personal Trainer certification through the American College of Sports Medicine (ACSM). **S**tudents who participated in the online yoga class practiced yoga asynchronously for one hour per week for a total of six-weeks. Students who participated in the F2F yoga class participated synchronously for one hour per week for a duration of six-weeks. Instruction in the online yoga class was made available in a video format through the college learning management system. Online students could access the course at their leisure. The F2F class was taught on campus at a specific time and place each week. Students in the online course uploaded videos of their weekly yoga practices as evidence of participation and flexibility measurements. Submitted videos provided fidelity of yoga practice and accuracy of measurements. Online students were then asked to describe their participation using video or online discussion forums. Discussions consisted of topics such as flexibility, anxiety, and how the course was affecting students personally. Feedback from the instructor was provided to all students on the discussion forum. Feedback was also provided to online students by sending them recorded videos and to F2F students by direct verbal feedback during class. The goals of the course in both formats were to increase flexibility and continued behavioural intentions to practice yoga beyond the semester, and to decrease straight, trait, and appearance anxieties.

Analysis

ANCOVA was used to compute the differences in the mean scores on the post STAI in order to determine if a statistically significant difference existed (a) between the post-assessment of the online yoga course and (b) between the post-assessment of the F2F yoga course, and to adjust for pre-test scores (RQ1). The AAIT was also used to determine if there was a change in appearance anxiety related to body image after completing either an online yoga course or a F2F yoga course. First, scores on the AAIT were analysed to identify whether students suffered from BDD. These data were analysed using a composite score of the total points possible, which is 40. These composite scores were then matched to the benchmark score of 27, which is the cut-off score for BDD. That is, scores above 27 indicate the presence of BDD whereas scores below 27 indicate the absence of BDD (Roberts et al., 2018). Moreover, to answer RQ1, the ANCOVA was conducted to compare post mean scores between the two modes of delivery using pre-tests as a covariant. Also, the AAIT data were analysed using a paired sample *t*-test to compare pre and post-test mean scores in each group.

To find out if there was a difference between a F2F yoga course and an online yoga course in students' scores on the Sit-and-Reach Test (RQ2), the SR test was administered to participants in both groups before they began the yoga class and again after they completed the yoga class. ANCOVA was used to compute the differences in the mean scores on the post SR tests in order to determine whether a statistically significant difference existed (a) between the post-assessment of the online yoga class and (b) between the post-assessment of the F2F yoga class.

To examine differences between a F2F yoga course and an online yoga course in student behavioural intentions towards yoga (RQ3), scores from the researcher-designed questionnaire of behavioural intentions were quantitatively analysed using an independent sample *t*-test to determine which mode of delivery (online or F2F) was the most effective in eliciting behavioural intentions. The variables were measured at a continuous level using a Likert scale.

The STAI, AAIT, and SR tests were all analysed using a paired sample *t*-test to compare each group on its pre-test and post-test mean scores for both online and F2F deliveries to examine if there was a significant difference from pre to post mean test scores. This would uncover any differences within the face-to-face yoga course and the online yoga course in students' scores on the pre/post State-Trait Anxiety Inventory, Appearance Anxiety Inventory test, and flexibility scores on the sit-and-reach test (RQ4).

For four of the measures (i.e., state anxiety, trait anxiety, appearance anxiety, and flexibility), ANCOVA was used to examine the differences between the means of two independent groups while adjusting for variability in the pre-test scores.

For the last measure, the paired samples *t*-test is suitable for examining within group differences on two variables (i.e., pre/post-test mean scores) for the same subject, separated by time. The paired sample *t*-test is an ideal analysis for the SR flexibility test as well as the STAI because administration of these questionnaires was separated by six weeks.

RESULTS

State anxiety

An ANCOVA was conducted to compare student scores on state anxiety between the F2F and online yoga groups and to control for any variation in pre-test. The pre-test score was loaded into the model as a covariate and after adjusting for it, there was a significant difference between the two groups on the post state anxiety score, with state anxiety being lower for students in the online course, $F(1,86) = 6.45$, $p < .05$, partial eta squared = .52, indicating a large effect size. Eta squared measures the proportion of the total variance in a dependent variable that is associated with the membership of different groups defined by an independent variable. Partial eta squared is a measure in which the effects of other independent variables and interactions are partialled out.

Trait anxiety
An ANCOVA was conducted to compare student scores on trait anxiety between the F2F and online yoga groups and to control for any variation in pre-test. The pre-test score was loaded into the model as a covariate and after adjusting for it, there was not a significant difference between the two groups on the post trait anxiety score, F (1,86) = .57, p = .453. There was a strong relationship between the pre trait and post trait anxiety score, as indicated by the partial eta squared value of .30.

Appearance anxiety
An ANCOVA was conducted to compare student scores on appearance anxiety between the F2F and online yoga groups and to control for any variation in pre-test. The pre-test score was loaded into the model as a covariate and after adjusting for it, there was a significant difference between the two groups on the post appearance anxiety score, with appearance anxiety being lower for students in the F2F course, F(1,87) = 5.34, p < .05. There was a strong relationship between the pre and post appearance anxiety scores, as indicated by a partial eta squared of .54.

Sit and reach flexibility
An ANCOVA was conducted to compare student scores on flexibility between the F2F and online yoga groups and to control for any variation in pre-test. The pre-test score was loaded into the model as a covariate and after adjusting for it, there was no significant difference between the two groups on the post sit and reach flexibility test scores, F (1,87) = 480, p = .49. There was a strong relationship between the pre sit and the post sit score, as indicated by a partial eta squared value of .84.

Behavioural intentions
An independent sample t-test was calculated to determine if there was a significant change in behavioural intentions as a result of participating in the online or F2F courses, comparing the mean scores of the post-test online and F2F yoga courses. An examination of Levene's Test was not significant, and therefore, equal variances were assumed. A significant difference was not found between the means of the two groups. The F2F group reported a mean of 40.82 (SD = 5.84) and the online group reported a mean of 38.80 (SD = 7.74), t(88) = 1.12, p = .26.

Paired sample T-Tests
State anxiety
A paired sample t-test was calculated to compare the state anxiety of the participants, comparing the mean pre-test score to the mean final post-test score of the students who participated in the F2F yoga course. The mean score for the pre-test was 45.27 (SD = 5.79), and the mean for the post-test score was 46.82 (SD = 6.23). There was no significant decrease in state anxiety from pre-test to post-test, t(44) = -1.79, p = .080. Also, a paired sample t-test was calculated to compare the state anxiety of the participants comparing the mean pre-test score to the mean final post-test score of the participants who participated in the online yoga course. The mean score for the pre-test was 44.09 (SD = 6.92) and the mean score for the post-test was 43.55 (SD = 6.63). However, this result was not a significant decrease from pre-test to post-test, t(44) = 1.06, p = .29.

Trait anxiety
A paired sample t-test was calculated to compare the trait anxiety of the participants comparing the mean pre-test score to the mean final post-test score of the students who participated in the F2F yoga course. The mean for the pre-test was 46.40 (SD = 5.30) and the mean for the post-test score was 45.62 (SD = 6.40). There was no significant decrease found from pre-test to post-test, t(44) = -.920, p = .36. Similarly, a paired

sample *t*-test was calculated to compare the trait anxiety of the participants comparing the mean pre-test score to the mean final post-test score of the students who participated in the online yoga course. The mean for the pre-test was 43.59 (*SD* = 5.95) and the mean for the post-test score was 42.82 (*SD* = 7.17). There was no significant decrease found from pre-test to post-test, $t(44) = .82$, $p = .42$.

Appearance anxiety

A paired sample *t*-test was calculated to compare the appearance anxiety of the participants comparing the mean pre-test score to the mean final post-test score of the students who participated in the F2F yoga course. The mean for the pre-test was 7.56 (*SD* = 5.53) and the mean for the post-test score was 6.13 (*SD* = 4.51). There was no significant decrease found from pre-test to post-test, $t(44) = 1.83$, $p < .05$. Likewise, a paired sample *t*-test was calculated to compare the appearance anxiety of the students comparing the mean pre-test score to the mean final post-test score of the students who participated in the online yoga course. The mean for the pre-test was 10.49 (*SD* = 7.96) and the mean for the post-test score was 10.44 (*SD* = 8.15). There was no significant decrease from pre-test to post-test, $t(44) = .065$, $p = .95$.

Sit and reach flexibility

A paired sample *t*-test was calculated to compare the *sit and reach flexibility* of the participants comparing the mean pre-test score to the mean final post-test score of the participants who participated in the F2F yoga course. The mean for the pre-test was 17.58 (*SD* = 3.64) and the mean for the post-test score was 18.84 (*SD* = 3.93). There was a significant increase found in scores from the pre-test to the post-test for the F2F yoga group, $t(44) = -.462$, $p < .05$. Additionally, a paired sample *t*-test was calculated to compare the sit and reach flexibility of the participants comparing the mean pre-test score to the mean final post-test score of those who participated in the online yoga course. The mean for the pre-test was 16.13 (*SD* = 4.03) and the mean for the post-test score was 17.22 (*SD* = 4.09). There was a significant increase in scores from the pre-test to the post-test for the online yoga group, $t(44) = -5.24$, $p < .05$.

ANCOVA analyses

When ANCOVA analyses were employed to control for variability between groups on the pre-test, only two dependent variables were found to be significant: state anxiety and appearance anxiety. State anxiety was lower for participants in the online course while appearance anxiety was lower for students in the F2F course, No statistically significant change was reported between the two dependent variables in the area of trait anxiety.

In the area of flexibility, when the ANCOVA was administered it was determined that when pre-test scores were used as a covariate, there was no significant difference between the groups in terms of flexibility, when comparing post-test scores for both the online and F2F deliveries. However, the paired sample *t*-tests showed that from pre to post both the F2F and online groups had significant increases in flexibility post test scores. In the area of behavioural intentions, there was no significant difference between groups.

When comparing the online and F2F courses individually using the paired sample *t*-test, for pre and post mean scores, it was discovered that in the area of state anxiety, students in neither course demonstrated a significant decrease in the area of state anxiety. With respect to appearance anxiety, the paired sample *t*-test also determined that there was no significant reduction within either method of course delivery.

Within the area of flexibility, however, it was determined that the paired sample *t*-test demonstrated a statistically significant increase in flexibility of the hamstrings for the students in both the F2F and the online yoga courses.

DISCUSSION

With the growth of online education, virtual yoga may offer a promising alternative to F2F yoga since it is generally regarded as more convenient, more accessible and more accommodating for individuals with different needs than F2F yoga. This present study showed that *trait anxiety* did not change for students in either group. However, there was a significant decrease of *state anxiety* in online students and a significant decrease in *appearance anxiety* for F2F students. Even so, within group analysis showed no significant reduction in any of three areas of anxiety for either form of course delivery. This finding is in contrast to that of other research (Bhosale, 2016) showing that yoga can decrease anxiety. It may be that with a larger and truly random sample more could be learned about the relationship between different types of anxiety among online yoga students. The F2F class in the present study consisted of a larger than normal population of football players who participated in the yoga class immediately after practice. The anxiety tests were administered after practice and aligned closely with the beginning of the season. The fact that these athletes are not guaranteed scholarships and can be cut from the team, may be a possible indicator as to why the yoga was not helpful for their state or trait anxiety. Furthermore, the present study may have been skewed because of the gender of participants between the two modes of course delivery. The online class consisted of 62% females and 37% males, while the F2F class consisted of 53% females and 46% males. There is research supporting the belief that females struggle more with appearance anxiety more so than males (Aderka et al., 2014; Wisting et al., 2018). If students in the online course had higher anxiety levels due to body image than students in the F2F class, it could be concluded that the online class would naturally have lower post-test scores than the F2F class, a class that was more evenly divided between male and female.

Both modes of course delivery increased *flexibility*, a finding that is consistent with that of another research (Tracy and Hart 2013). However, no significant difference occurred between groups indicating that F2F and online course delivery is equally effective in increasing flexibility. Since the only area that demonstrated any significant change was the flexibility in students in both modes of delivery, ensuring that such a component is available in any course may be beneficial to several groups of people, including seniors, physical education teachers, athletes, and patients of chiropractors and physical therapists. This concurs with previous research on the benefit of yoga for flexibility (Halder et al. 2015; Polsgrove et al., 2016).

There was no significant change in students' *behavioural intentions* towards exercise and yoga in either group. There was a slight difference in behavioural intentions between the two delivery modes with F2F students reporting a slightly higher mean score (M = 40.82) than the online students (M = 38.80). It should be noted that the total maximum score for the behaviour assessment was 49 points, indicating that both delivery methods had moderately high scores related to perceived behavioural intentions. It is possible that the reason for the slightly higher behavioural intention in the F2F course could be due to the fact that the instructor was physically present and thereby, was able to offer more immediate positive reinforcement to F2F students.

CONCLUSIONS

With the results from prior research and the current research study suggesting that online yoga may be equally as effective as F2F yoga, by offering more opportunities for college students and other populations to take online yoga courses, the same benefits may result. Particularly because an online form of delivery is less intimating and more attractive for individuals who are obese, out of shape, physically challenged, etc., online yoga may be a promising method for reducing and preventing long-term health concerns that plague our nation. Additionally, flexibility is a key component to living a healthy lifestyle (Bradley, 2011) so fall-prevention programs have become perceived as essential in order to reduce the number of falls among seniors. With both formats (i.e., online and F2F yoga) demonstrating an increase in flexibility, the online yoga option could potentially help seniors who are not as mobile as others, and/or who live in colder climates where winters can create challenges for attending F2F yoga course. As well, F2F courses might also be offered at senior centres in order to help seniors avoid falls, and generally, live longer and healthier lives. More research is key to understanding the impact that online yoga has and will have on obesity, flexibility and anxiety, as well as making yoga more accessible to individuals who need to increase flexibility and decrease anxiety. Further research also might examine more specific populations such as athletes or seniors to see which modes of deliveries are more effective and why.

AUTHOR CONTRIBUTIONS

Judy Lambert is responsible for the supervision and writing the first draft; Robyn Miller is responsible for conceptualization, methodology, performing the experiments, and data collection. All authors discussed the results and contributed to the final manuscript.

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No funding agencies were reported by the authors.

DISCLOSURE STATEMENT

We acknowledge that the experiments comply with the current laws of the United States where they were performed. We certify that Bowling Green State University approved the protocol for this investigation and that all experimentation was conducted in conformity with ethical and humane principles of research.

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ORIGINAL ARTICLE

Doping prevalence and attitudes towards doping in Dutch elite sports

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ABSTRACT

The use of performance enhancing substances among elite athletes is a well-known phenomenon, but data on prevalence are inconsistent. The aim of this study was to investigate (1) the prevalence of doping use in Dutch elite athletes and (2) the attitude of elite athletes with regard to the use of performance enhancing substances. A total of 272 elite athletes completed an online questionnaire about doping use using the randomised response method and about their attitude towards the use of performance enhancing substances. The estimated prevalence of the use of doping among Dutch elite athletes during the last 12 months was 12.5 percent (95% CI 3.0 to 24.7%). The prevalence for using non-prohibited medication (without medical necessity) during the last 12 months was 15.4% (95% CI 7.1 to 23.7%). One in four athletes (23%) accepts the use of medication on prescription without a medical necessity, in order to enhance their performance. Doping prevalence among Dutch elite athletes is estimated at 12.5%, with a confidence interval from 3 to 25%. Acceptance of other performance enhancing substances is relatively high demonstrating that educational and preventive programs are essential in the fight against doping and the protection of athletes.
Keywords: Physical activity psychology, Doping, Elite sports, Performance enhancement, Randomized response, Doping prevalence.

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INTRODUCTION

The use of performance enhancing substances among elite athletes is a well-known phenomenon. Performance enhancing substances are defined as substances that are not part of a typical dietary intake and are meant to improve the performance. There is a wide range of substances that may improve performance. This ranges from substances that are not prohibited in sport such as vitamins and common supplement ingredients, to substances prohibited in sport such as anabolic or stimulating agents, which are popularly defined as doping. The use of doping in elite sports not only affects the integrity of sports, but also poses a risk for the health of athletes. The seriousness of the adverse effects strongly depends on the substance and way of using, but ranges from relatively mild symptoms to fatality (Albano et al., 2021; Anderson et al., 2018; Gild et al., 2022; Salamin et al., 2018; Siebert and Rao, 2018; Smit et al., 2022).

Anti-doping agencies are committed to achieving a doping-free sport. In order to achieve this goal, they use different strategies, such as education, deterrence, detection and enforcement. However, the lack of data on doping prevalence makes it difficult to assess the effectiveness of their efforts (Gleaves et al., 2021). Due to the sensitivity of the subject, studies investigating doping use are complex. There are different approaches to investigate doping prevalence and De Hon et al. have investigated all pros and cons of these methods (Hon et al., 2015). They conclude that researchers should use harmonised definitions of the terms "*doping*" and "*elite sports*" and that using questionnaires using a randomised response approach is preferred over "*regular*" questionnaires. They also state that current worldwide doping prevalence lies probably between 14 and 39%, but that this finding needs further confirmation (Hon et al., 2015). Although the authors state that this estimate may differ considerably between subgroups, it is most likely closer to the truth than the 1-2% of the positive test results on prohibited substances. A more recent study on doping prevalence reported a prevalence of 43.6% (with a 95% confidence interval of 39.4–47.9%) among athletes at the International Association of Athletics Federations (IAAF) 2011 World Championships (Ulrich et al., 2018). An ever higher prevalence of 57.1% (95% CI of 52.4–61.8%) was observed among athletes at the 12th Quadrennial Pan-Arab Games. However, it is important to note that the data of these two studies were recently critically reviewed and re-analysed, resulting in lower estimates of 21.2% and 10.6% respectively (Petróczi et al., 2022).

Nevertheless, these data demonstrate relatively high estimates of doping prevalence in combination with a wide range of data. This does not only demonstrate the magnitude of the problem, but also that gathering data on this topic should be a priority. As Pielke described in a commentary paper: "*Sport will not begin to confront its doping problem until asking and answering, "how many?" becomes a priority"* (Pielke, 2018).

However, although the "*how many*" question is important, it is useful to combine this knowledge with data on athletes' attitudes towards the use of performance enhancing substances in general. Backhouse and colleagues demonstrated that doping use, but also attitudes and believes about doping were different between athletes who used performance enhancing supplements and athletes who did not. Doping was three and a half times more prevalent in supplement users compared to non-users and users had significantly more positive attitudes towards doping (Backhouse et al., 2013). They introduced the "*gateway hypothesis*", where athletes who use non-prohibited substances in order to increase their performance are a risk group for transition towards doping. Doping is associated with attitude towards doping. In order to develop efficient preventive strategies aiming to prevent doping in elite sports, knowledge of attitudes and believes about doping, in addition to data on prevalence, is relevant.

As for Dutch elite sports, reliable and current data on the use of and the attitude towards doping use is lacking. Therefore, in order to expand the knowledge on both prevalence measurements and potential risk behaviour related to doping use, we investigated (1) the prevalence of doping in Dutch elite athletes and (2) the attitude of elite athletes with regard to the use of performance enhancing substances.

MATERIALS AND METHODS

Participants

A total of 831 elite athletes, defined by having an official "*elite-status*" assigned by the Dutch Olympic committee (NOC*NSF), were invited by NOC*NSF to participate in the study. The elite status is generally assigned when athletes perform on top-8 level worldwide (at world championships of events of a similar level) or when they qualify for the Olympic or Paralympic games. The athletes received an email with an invitation to complete an online questionnaire. In order to achieve an optimal response rate, the email invitation was accompanied by a (digital) letter from the current minister of Medical care and Sports. In this letter she endorsed the importance of this study and the cooperation of the athletes. All athletes received one reminder per email. Data were collected between September 30th and November 12th 2020.

This study is not subject to the Medical Research Involving Human Subjects Act (WMO), therefore approval by an ethics committee was not required.

Measures

Questionnaire

The questionnaire contained questions about demographic factors (age, sex, type of sport), attitude with regard to the use of performance enhancing substances and four questions about their personal doping use during the past 12 months (anabolic agents, blood manipulation, stimulating agents and other prohibited substances/methods, as published by the World Anti-Doping Agency). Additionally, the athletes were asked about their use of non-prohibited medication in order to enhance their performance. For these five questions, the randomised response method was used.

Procedures

Randomised response method

The consequences for an elite athlete of admitting to doping can be immense. Consequently, studies investigating doping prevalence are often confounded by respondents giving dishonest and socially desirable answers. Using the randomised response (RR) method has shown to be effective in decreasing the level of this type of bias in questionnaires about sensitive topics (Lensvelt-Mulders et al., 2005). De Hon et al. performed a review on various methods for the assessment of doping prevalence. They conclude that the RR method (in combination with models of biological parameters) is the most accurate way of estimating the prevalence of doping in elite sports (Hon et al., 2015).

When using the RR method, researchers can guarantee respondents full anonymity as the researchers deliberately introduce a mathematical confounder. There are multiple variants of the RR method and in the current study the Kuk method was used (Kuk, 1990). Previous research among Dutch elite athletes showed that results obtained using the Kuk method were more reliable compared to the results from the forced response method (Duiven and de Hon, 2015). With the Kuk method, participants get questions that can be answered with either A or B. However, the meaning of both options (A = yes and B = no, or A = no and B = yes) is random and is defined by chance, which in this study was determined by the rolling of two dice by the participant. The chance distribution was as follows; when the sum of both dice was 2, 3, 4, 5, 6, 7, 8 or 9 then

A = yes and B = no (30/36). When the sum of both dice was 10, 11 or 12 then A = no and B = yes (6/36). As a results of this mathematical confounding, individual answered cannot be verified and prevalence estimations can only be made on a group level, using specific statistical analyses methods.

Analysis

The univariate prevalence estimates and standard errors for the five randomised response questions were obtained with the standard Kuk model (Kuk, 1990). The total prevalence of using any of the four prohibited doping substances was estimated using a randomized response log-linear model (van den Hout and van der Heijden, 2004). The reported total prevalence estimate is based on the mutual independence model, which in terms of the Akaike Information Criterion (AIC) performed best in comparison to the models including one or more interactions between the doping substances. The 95% confidence interval for the total prevalence estimate was obtained using the non-parametric bootstrap. As goodness-of-fit test for the log-linear models the G test is used; it has an asymptotic chi-squared distribution, and a non-significant test result indicates an adequate fit.

The comparison of projected prevalence were performed with the Mann Whitney U test. Categorical variables were analysed using the chi-square test. Analyses were performed using R (version 4.0.0) and IBM SPSS Statistic (version 27.0), with a significance level of 5%.

Pilot study

Although the RR method has shown to be effective in decreasing levels of bias in questionnaires on sensitive topics, a doping prevalence study among Dutch elite athletes from 2019 demonstrated that the method can be too complex for participants (Dopheide et al., 2020). Only when instructions are clear and feasible, participants will follow them which is absolutely essential for a reliable estimation on doping prevalence. In order to test whether the instructions for the RR method were clear and feasible, a pilot study was performed.

In this pilot study the RR method was tested in a group of former elite athletes, who's "*elite status*" ended in 2016 or 2017. These former athletes (n = 451) received a digital questionnaire including questions on demographic factors followed by 5 questions on doping use, using the RR method with rolling of the dice. The five questions with the RR method were about personal doping use with regard to anabolic agents, blood doping, stimulation agents, other prohibited substances/methods and non-prohibited medication, during their active career as an elite athlete. Subsequently, the former athletes were asked about the clarity of the instructions, feasibility of the method and the level of confidence they had in the anonymity of the method.

The level of response was relatively low (n = 46, 10%) but representative for the total population of former athletes. The majority (96%) reported that the instructions were clear enough and only 3% was not confident the method was completely anonymous. The log-linear analyses of the RR data with the mutual independence model demonstrated that no unexpected answering patters were observed and that the model fit the data ($X^2 = 16.7$, df = 11, $p = .12$). This suggests that participants most likely followed the instructions and answered the questions accordingly.

The questions about the clarity of the instructions yielded some useful suggestions, resulting in revisions of the instructions and answer categories.

RESULTS

Response profile
Of the 831 athletes who were invited, 272 (partly) completed the questionnaires, resulting in a response rate of 33%. Of the 272 participants, 249 completed the entire questionnaire. Data from incomplete questionnaires were included in the analyses, as there was no indication that these incompletions were caused by a specific confounder. Table 1 shows the response profile of the elite athletes. Female, younger and team athletes were slightly overrepresented compared to the target population.

Table 1. Response profile elite athletes.

	Target population (n = 831)	Response population (n = 272)
Sex (% male)	48	40
Age (%)		
<23 years	31	36
24-29 years	41	42
≥30 years	28	22
Discipline (%)		
Olympic	78	72
Paralympic	17	21
Non-Olympic	5	7
Type sport (%)		
(Semi)-individual	66	60
Team	34	40

Doping prevalence
A total of 249 elite athletes completed the four questions about the use of different types of doping during the past 12 months (anabolic agents, blood manipulation, stimulating agents and other prohibited substances/methods) using the RR method.

Table 2 shows that the estimated prevalence of the use of anabolic agents in Dutch elite athletes during the past 12 months was 2.1 percent, with a 95% CI of 0.0 to 9.3 percent. For the use of blood manipulation, the estimated prevalence was 0.3 percent, with a 95% CI of 0.0 to 7.3 percent. The use of stimulating agents demonstrated an estimated prevalence of 2.7 percent, with an 95% CI of 0.0 to 10.0 percent, whereas the estimated prevalence of other prohibited substances/methods (such as glucocorticoids, bèta-2-agonists, diuretics or other prohibited hormones) was clearly higher with 8.1 percent (95% CI of 0.4 to 15.9%).

Table 2. Estimated prevalence of different types of doping and total prevalence among Dutch elite athletes (n = 249).

Type	Prevalence (%)	95% CI	*p*-value
Anabolic agents	2.1	0.0 – 9.3	.565
Blood manipulation	0.3	0.0 – 7.3	.933
Stimulating agents	2.7	0.0 – 10.0	.463
Other prohibited substances/methods	8.1	0.4 – 15.9	.040
Total prevalence*	12.5	3.0 – 24.7	

*Note. CI: confidence interval. *Total prevalence is lower than the sum of the different types, because athletes reported combinations of more than one type of doping.*

For the estimation of the total prevalence of doping use, data on the four types of doping was combined and the possibility of using combinations of different types of doping was taken into account. This resulted in an estimated overall prevalence of 12.5 percent, with a 95% CI of 3.0 to 24.7 percent (Table 2). The large confidence interval is a result of the RR method, combined with the relatively small number of respondents. The goodness-of-fit test shows the model fits the data ($X^2 = 8.25$, df = 11, $p = .69$).

Non-prohibited substances
Athletes were asked whether they had used any type of medication which was not on the WADA Prohibited List, in order to enhance their performance, during the past 12 months. In the questionnaire it was specified that using the medication was not medically necessary for the athlete. The prevalence among Dutch elite athletes for using non-prohibited medication during the last 12 months is 15.4% (95% CI 7.1% to 23.7%, $p < .001$).

Intention to dope and projected doping prevalence
Intention to dope
Athletes were asked (without the RR method) if they ever had the intention to dope. A total of 3% of athletes (n = 8) reported having intentions to dope.

Two of these athletes reported that their intentions were to use doping in recreational setting, instead of doping in order to enhance their performance. One athlete explains why he considered doping:

> *"When you see the major advantages that your competitors have because they dope and you don't, it makes you think and consider doing it yourself. Then, if you reach the top, you are "set for life"." (elite athlete in non-Olympic discipline*)

Doping prevalence projection
All elite athletes were asked about what percentage of athletes they think doped during the last 12 months. This was asked for the situation within the field of their own sport in the Netherlands and internationally. This projected prevalence should not be interpreted as a measure for doping prevalence (due to egocentric bias),[1] but merely as an indication of the subjective difference from the athletes' perspective, between the national and international tour.

Dutch elite athletes estimate the use of doping within the field of their own sport in the Netherlands at 3.9% (95% CI 2.9 to 5.0), whereas the estimation of doping use in international events is significantly higher at 11.0% (95% CI 9.4 to 12.7, $p < .001$ for difference). Athletes active in a (semi-) individual sport had lower estimations for the prevalence on national level (3.1%) compared to athletes participating in team sports (5.5%, $p = .023$). No difference between team and (semi-) individual athletes was observed for the estimated prevalence on international level.

Attitudes towards using performing enhancing substances
Regarding other substances (such as supplements and medication) which may be performance enhancing, but are not listed as prohibited, the attitudes of athletes towards using these substances were investigated.

The large majority of the Dutch elite athletes (94%) considers the use of vitamins and minerals in order to enhance the performance, acceptable (Figure 1). The use of supplements such as caffeine, creatine, beta-alanine and sodium bicarbonate is also seen as acceptable by the majority of athletes (86%). Besides vitamins and other supplements, some athletes use non-prohibited medication to enhance their performance. This medication can be divided in medication for which no prescription is needed (over-the-counter medication, such as paracetamol of ibuprofen) and medication for which a prescription by a medical professional is needed. Medication without prescription is seen as acceptable by 74% of athletes. The extent to which the use of non-prohibited medication for which a prescription is needed is accepted, depends on the medical necessity. When an athlete has a medical condition for which he or she needs to take prescribed medication (in order to enhance their performance), this use is accepted by 87% of athletes. Younger (aged <23) athletes are more likely to consider the use of medication with a medical condition acceptable compared to older (aged >35) athletes (82% and 42% respectively, not in figure). The use of medication without medical necessity was considered unacceptable by 57% of athletes. Nevertheless, almost one in four athletes (23%, Figure 1) believes using prescribed medication (no doping) solely for the use of enhancing performance, is (completely) acceptable. Finally, doping is considered somewhat or completely unacceptable by almost all athletes (99%). It should be noted however, that this was a "*regular*" question, without the use of the RR method.

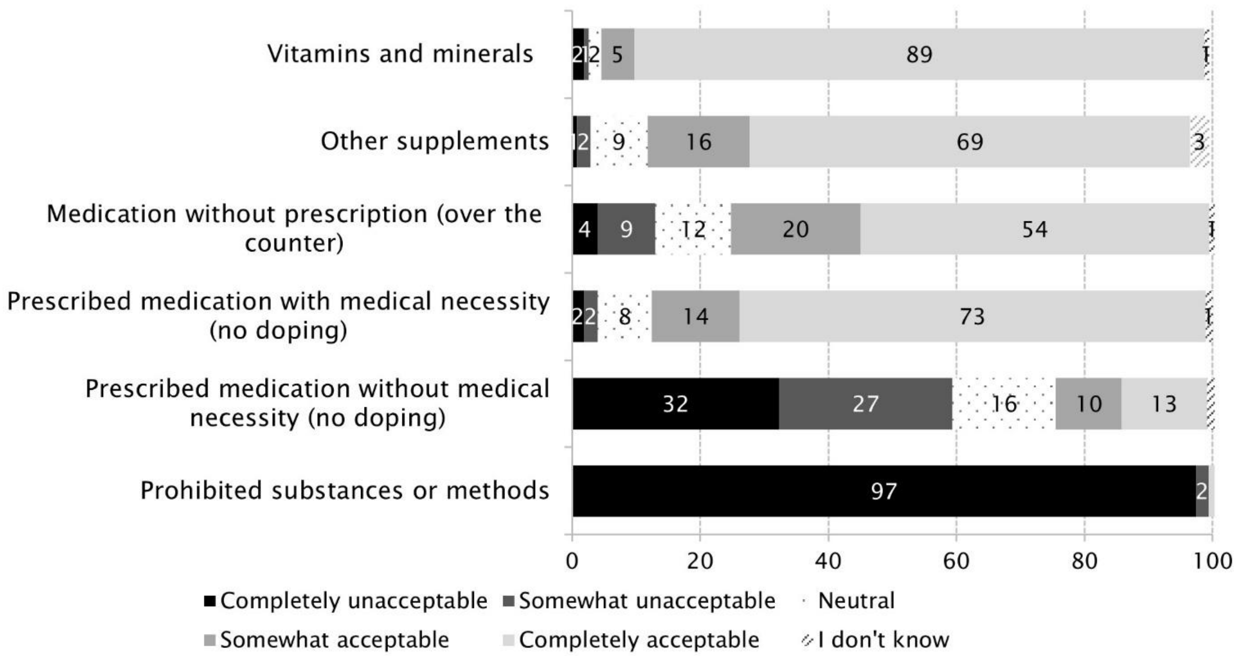

Figure 1. Level of acceptance of using substances by elite athletes in order to enhancing their performance (n = 272).

Deterrents for doping use

Athletes' deterrents to dope were investigated. Athletes were asked to what level they considered six potential motivations to not use doping as (un)important. The Dutch elite athletes report "*fair play*" as the most important deterrent to use doping (96%, see Figure 2). Health risks and the responsibility as a role model were also reported as important deterrents. Female athletes are more likely to consider their responsibility as a role model an important deterrent compared to male athletes (92% and 77% respectively, p = .01, not in figure). Fear of sanction or punishment was only considered important by 51% of athletes.

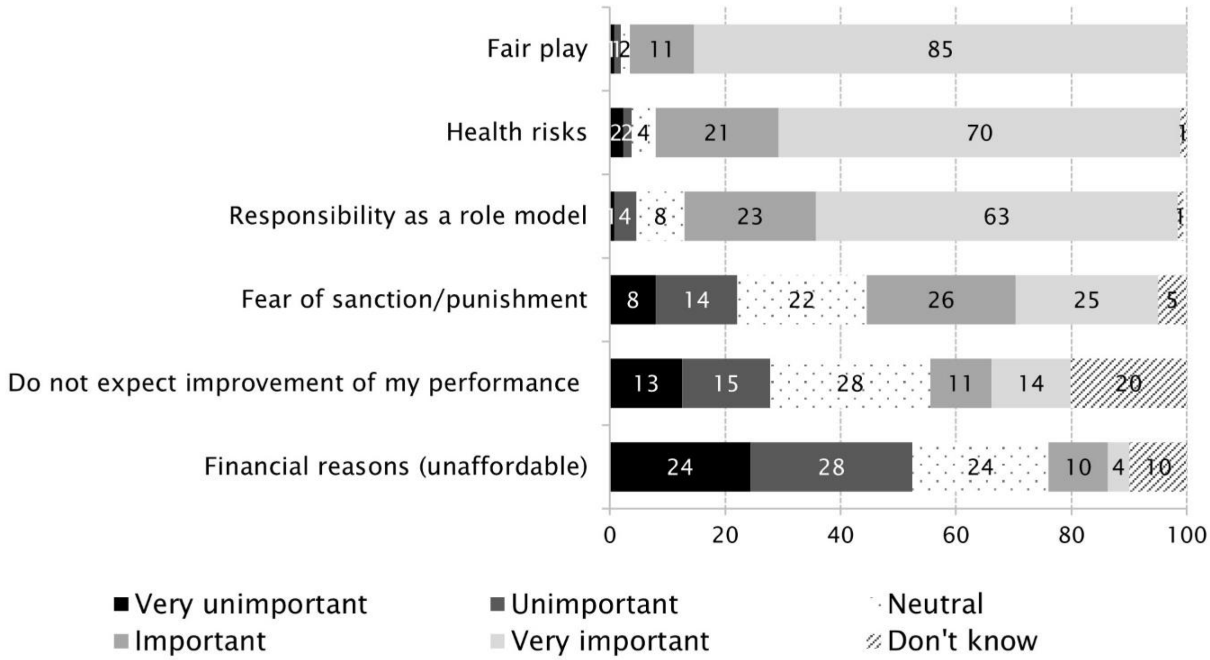

Figure 2. Importance of deterrents to use doping according to elite athletes (n = 263).

DISCUSSION

This study demonstrates that doping prevalence among Dutch elite athletes is estimated at 12.5%, with a confidence interval from 3 to 25%. This overall estimation includes the use of anabolic agents, blood manipulation, stimulating agents, other prohibited substances/methods and combinations of these. When looking at individual types of doping, the estimated prevalence was highest for "*other prohibited substances/methods*" (such as glucocorticoids, bèta-2-agonists, diuretics or hormones other than anabolic agents) with an estimated prevalence of 8.1 percent, followed by stimulating agents (2.7%), anabolic agents (2.1%) and blood manipulation (0.3%).

The overall prevalence of 12.5% is below the estimated worldwide doping prevalence range reported by de Hon and colleagues (14-39%) (Hon et al., 2015) but falls within the range reported in a more recent overview of doping prevalence studies (3.2-57.1%) (Gleaves et al., 2021). In this review, studies were included using different methods for assessing doping prevalence. In total 9 studies were identified where prevalence was estimated using the RR method, but populations were different in terms of type of sport (elite athletes of all sports, or only athletes from one specific sport) or performance level (regional, national or international level). Boardly et al. investigated doping prevalence in high-level athletes from Australia (n = 261), the UK (n = 300), and the USA (n = 261) and reported an estimated prevalence of 13.9% (Boardley et al., 2019). However, the definition of "*high-level*" was unclear. Another study investigated seasonal doping use among Danish elite athletes (n = 771) using an online survey with RR method. They reported an estimated prevalence of 30.6% (95% confidence interval 22.6–35.7%). However, the authors stated that results may partially be biased by the high proportion of respondents who did not answer according to the RR method instructions (30.6%) (Elbe and Pitsch, 2018). Somewhat similar results were reported by Pitsch and colleagues in 2007 (Pitsch et al., 2007). In elite athletes performing on international level, they reported a range of 12.1 to 31.1% for doping use in the current season. Finally, Ulrich and colleagues investigated doping prevalence among elite athletes at two large athletics events, using RR method. They reported estimated prevalence of past-year doping use of 30% and 45% at two elite-level events in 2011 (Ulrich et al., 2018), but a recent re-analysis of these data resulted in somewhat lower estimations (Petróczi et al., 2022). It should be noted that comparison of these numbers is difficult for multiple reasons. First, in contrast to the studies by Boardly, Pitsch, Elbe and the current study, Ulrich and colleagues investigated athletes from a specific sport (athletics) whereas the other studies included elite athletes from a wide range of sports. Another important aspect which makes comparison difficult is the definition of "*elite sports*". Although in the present study this was clearly defined as having an official "*elite-status*" assigned by the national Olympic committee (indicative of performance on top-8 level worldwide or participating at the Olympic or Paralympic games), this was not clear for all studies. Including athletes performing on a lower level may yield different doping prevalence numbers, as these athletes receive less education, testing frequency is lower and the (perceived) gains of doping use may be different.

Besides the use of the typical types of doping the prevalence of the use of non-prohibited medication (without medical necessity) was studied using the RR method. This resulted in an estimated prevalence of 15.4% (95% CI 7.1% to 23.7%). The estimated prevalence of non-prohibited medication seems to be in the same range as doping. There seems to be a large difference between the two however, regarding the level of public acceptance. When asked directly (without the RR method), 99% of athletes stated that they consider doping somewhat or completely unacceptable. This number was significantly lower when athletes were asked to what extent the use of medication without medical necessity was considered acceptable. Almost one in four athletes (23%) considers using medication without medical necessity, solely for the use of enhancing performance, as (completely) acceptable. This finding suggest that use of improper medication seems to be more acceptable among athletes than doping. Prevalence are however in a similar range. This may be a result of the use of the RR method, suggesting that the use of the RR method further enhanced the feeling of complete anonymity for the respondents, resulting in more honest answers.

Besides doping and prescribed medication without medical necessity, there are other substances that can enhance athletic performance. These substances are not on the WADA Prohibited List and are sometimes considered a "*grey area*" regarding the level of acceptance. Among Dutch elite athletes, the majority has no problem with the use of vitamins and minerals (94%) or other food-related supplements such as caffeine supplements (86%). The use of over-the-counter medication (such as painkillers) in order to enhance performance, is also accepted by the majority of athletes (74%). Generally, Dutch athletes have a positive attitude towards these over-the-counter, non-prohibited performance enhancing substances.

The use of prescribed medication and high level of acceptance of other supplements might be a risk factor for increasing levels of doping use. Backhouse and colleagues demonstrated that athletes who use nutritional supplements have a more positive attitude towards doping and a higher chance to dope. They state that athletes using legal substances to enhance performance may therefore form a risk group for transition towards doping (Backhouse et al., 2013). This potential risk in supplement users, together with the relatively high level of acceptance of supplements and medication among Dutch athletes, advocates proper education on this topic in both athletes and support personnel.

The potential effectiveness of (preventive) educational programs is further strengthened by the finding that the importance of fear of sanction or punishment as a deterrent for doping use, is relatively limited. Instead, athletes state that fair play, potential health risks and their responsibility as a role model are the most important deterrents to dope. This is in line with a previous study demonstrating that the decision to start doping is extremely complex and that athletes do not appraise current anti-doping strategies as highly effective (Kegelaers et al., 2018). Educational programs should therefore not only include anti-doping regulations but should also (or especially) include topics such as potential health risks, physical and psychological side effects or awareness about the effects they have as role models on others when they are caught doping. The latter should support athletes in making decisions based on their personal values and increase their sense of responsibility (values-based education).

Studies investigating doping prevalence always have the limitation of the unwillingness of athletes to participate and to disclose their doping use. This may lead to selection bias, as athletes who dope are less likely to participate in studies, but also to untruthful answering of the questions regarding doping. Many approaches to assess doping prevalence have been described, with various levels of quality and reliability (Gleaves et al., 2021). Although previous research has shown that a survey using the RR method is one of the more reliable methods, there are still limitations (Hon et al., 2015). Compared to traditional questionnaires, RR methods decrease the chance respondents give socially desirable answers. This results in higher prevalence estimates, which are closer to the truth (Lensvelt-Mulders et al., 2005). A major limitation of the approach, however, is the level of uncertainty in the estimated prevalence. This uncertainty is caused by the use of the chance mechanism and consequently the outcome is reported as a confidence interval, instead of a single percentage. Especially in small samples (which is common in many countries when studying populations of elite athletes) the results provide an indication of the doping use in the studied sample, but numbers are difficult to compare with other studies or when follow-up assessments are done. Moreover, the uncertainty limits the potential to use this method for the evaluation of preventive anti-doping programs. Studies focusing on other parameters, like athletes' attitude towards doping may be of higher value for this purpose.

The types of doping investigated in this study were anabolic agents, blood manipulation, stimulating agents and other prohibited substances/methods. One relatively new and fast developing method which was not specifically defined is gene doping. In gene doping, gene therapy products can be used to stimulate production of bodily substances such as erythropoietin or human growth hormone, in order to improve sports performance (Haisma and de Hon, 2006). Even though gene doping is listed on the WADA Prohibited List (category M3) and was therefore categorized in "*other prohibited substances/methods*" in our study, it may be of interest to investigate gene doping as a separate category in future studies. The search for new, accurate detection methods continues, (Baoutina et al., 2022; Cantelmo et al., 2020), but so far there have been no identified cases of gene doping in elite sports. Future prevalence research should clarify whether this is because gene doping is not used in elite sports, or because current detection methods are insufficient.

CONCLUSION

This study demonstrated that doping use is present among Dutch elite athletes. The prevalence during the last 12 months lies within a range of 3.0 to 24.7%, with a point estimate of 12.5%. The acceptance of other performance enhancing substances, including improper use of prescribed medication, is relatively high. In light of these findings, together with the result that fear of sanction or punishment was found to be a relatively unimportant deterrent for doping, educational and preventive programs are essential in the fight against doping and the protection of athletes.

AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: L. Balk, M. Dopheide, E. Duiven; data collection: L. Balk, M. Dopheide, E. Duiven; analysis and interpretation of results: L. Balk, M. Dopheide, M. Cruyff, E. Duiven, O. de Hon; draft manuscript preparation: L. Balk, O. de Hon. All authors reviewed the results and approved the final version of the manuscript.

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ORIGINAL ARTICLE

The difference in well-being between handball players and ones not physically active

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ABSTRACT

Subjective well-being is a good indicator of the individual's psychological health. High levels of subjective well-being have been found in adolescents who are regularly physically active, less prone to negative emotions, more easily able to cope with life's problems and challenges, have a lower body mass index, and exhibit higher levels of life satisfaction. The participants in this research were adolescents from the Republic of Croatia, N = 756, of which 407 (53.8%) were handball players and 349 (46.2%) were adolescents from the control group not physically active. The research was conducted in elementary schools and handball clubs with adolescents in 2006 and 2007. Instruments used in this research are Life Satisfaction Scale and PANAS. Adolescent handball players are more satisfied with life, they express higher levels of positive affect and lower levels of negative affect compared to adolescents who are not involved in some form of kinesiology activities.
Keywords: Physical activity psychology, Sport psychology, Adolescents, Life satisfaction, Negative affect, PANAS, Positive affect.

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INTRODUCTION

The concept of subjective well-being includes evaluations of one's life in the present moment and the future through emotional reactions and evaluations of satisfaction both with a particular segment of life and life as a whole. The evaluation criteria are exclusively personal and subjective. Certain life situations and conditions can be considered positive and successful, such as a rich social life, a high-ranking job, completing prestigious faculties, and similar circumstances. Although these are all positive factors that certainly help in achieving subjective well-being, they cannot be evaluated individually. Individuals may have a different understanding of what is important in life and what gives them satisfaction. It is also possible that dissatisfaction in one aspect of life threatens positive affect from all other aspects. Life circumstances, opportunities, and events are evaluated through affective states and cognitive processes.

The affective component of subjective well-being refers to the frequency and change of affective states, positive and negative moods, i.e., experiencing positive emotions more often with reduced experiencing or even the absence of negative emotions. It differs from the cognitive component, primarily because emotions are reactions to either internal or external stimuli and are mostly of shorter duration. The cognitive component of subjective well-being is self-assessment of life circumstances, satisfaction with life as a whole, and satisfaction with its segments (Diener, Oishi, and Lucas 2003). A conscious assessment of one's own life can reflect an individual's far-reaching point of view. It can also provide insight into attitudes, values, tendencies, and even goals, while, for example, an affective assessment can provide insight into some subconscious aspects. Although the components of subjective well-being are related, they are considered as relatively independent concepts.

Research on slightly more than 2,000 adolescents in Spain showed that among physically active adolescents, more individuals satisfied with life were found to have higher levels of self-efficacy (Reigal Garrido et al., 2014). The aforementioned researchers also established that adolescents who choose sports activities to spend their free time show higher levels of subjective well-being than those who are not involved in any form of sports activity. In this research, a statistically significant difference was found between the observed groups in terms of life satisfaction and negative and positive affect. Some researchers emphasize that both the type of physical activity and its intensity contribute to different levels of subjective well-being. Differences in subjective well-being and levels of life satisfaction depend on different intensities and durations of physical activity (Smedegaard, Christiansen, Lund-Cramer, Bredahl, and Skovgaard 2016; Groffik, Mitáš, Jakubec, Svozil, and Frömel 2020; Chmelik et al., 2021). It should be emphasized that causality may go in both directions, that is, people with higher levels of subjective well-being choose sports activities more often. Higher levels of life satisfaction are recorded by those who prefer physical activity compared to those who are more inclined to activities that do not require physical engagement (Brown et al. 2015) However, a systematic search of the relevant databases of scientific papers (Google Scholar, Eric and Scopus) shows that there is not much research on the relationship between handball and subjective well-being. Therefore, in this paper, we started from the null hypothesis, i.e., that there is no difference in the mean level of subjective well-being between handball players and the control group.

METHOD

Participants and study design

The participants were recruited from the two cohorts which were born in 2006 and 2007 and were 13 and 14 years old at the time of the data collection. We used a quasi-experimental study design which included the comparison of the two groups that primarily differed in their level of physical activity.

1) The quasi-experimental[1] (E) group consisted of 407 participants engaged in the organized handball training program. Three criteria were used for including participants in the E group of handball players: i) they were engaged exclusively in the handball training program, ii) they had practice at least four times a week, and iii) they practice for at least a year in a handball club or handball school. Croatian handball clubs were contacted and responded in large numbers, 91%. Demographic data were collected, as well as on the length and intensity of training.

2) The control (C) group consisted of 349 participants that are not involved in any form of organized physical activity. The criteria for including participants in the control group of adolescents were that they were not engaged either in handball or in any other sport-training program or any kinesiological activity. Thus, the logic of the study design was to compare differences in the mean level of the well-being components between these two groups. Adolescents filled out the questionnaires personally using the pen-paper method. The research started in the city of Zagreb. Handball clubs reacted more promptly and got involved in research faster than primary schools. In agreement with coaches and heads of handball schools, tests were planned before or after training in the spaces they used. The research was approved by the Ethics Committee of the Faculty of Teacher Education, University of Zagreb. Adolescents had questions about what will be done with these answers, and how they will be used. The professional service was most often involved in communication and cooperation, given the limited access to institutions due to the measures imposed due to the SARS-CoV-2 virus pandemic.

The main goal of the research is to examine whether there is a connection between the level of subjective well-being (satisfaction with life, positive/negative affect) and personality traits between adolescents who play handball as a kinesiology activity and those who are not actively involved in kinesiology activities.

Measures

Two measures for the three components of the well-being concept were used: 1) Life satisfaction scale (Penezić, 1996) was used as a measure of the cognitive component of well-being. 2) The Croatian adaptation (Križanić, 2013) of the Positive and Negative Affective Schedule - PANAS (Watson, Clark, and Tellegen (1988) was used as a measure of positive and negative affect which are theoretically classified as affective components of well-being. Penezić (2006, p. 646) defines life satisfaction as "*the cognitive evaluation of the entire life, through which each individual evaluates his own life*". The Life Satisfaction Scale itself is constructed so that it consists of 20 items, where 17 items assess global satisfaction, while 3 items assess situational satisfaction. Life satisfaction is a measure of the cognitive component of subjective well-being with scores varying from 1 to a maximum of 5.

Concerning the construct of subjective well-being, which consists of a cognitive component (satisfaction with life) and an affective component, the PANAS scale was taken as a measure of the frequency of positive and negative emotions, i.e. affects in the adapted Croatian version (Križanić 2013). The scale consists of 16 items, 8 for measuring positive affect and 8 for measuring negative affect. The research participant rates each item to what extent they feel this way in the last week on a Likert scale from 1 (not at all) to 7 (extremely). The total score for a particular dimension is also a linear combination of responses. A higher score indicates a greater presence of affect, while the theoretical range of scores varied from a minimum of 1 to a maximum of 7.

[1] *The term "experimental" was used in this text although the engagement in sport activity was not experimentally manipulated but rather quasi-experimentally controlled via controlling the including criteria for the E and C groups.*

RESULTS

Before the analyses aimed at testing the hypotheses, preliminary analyses were conducted in which the distribution of the results was examined. Although it was shown that the distribution of the results deviates from normality, this deviation was minimal as can be seen from the relatively low values of the skewness and kurtosis indicators.

For the Life satisfaction scale, the deviation is slightly higher, which is a typical result in the literature, but, in our opinion, does not invalidate the implementation of parametric statistical procedures.

In this study, Cronbach's alpha coefficient for positive affect was 0.84 for the total sample and 0.82 for the experimental group of handball players, and 0.84 for the control group. For the negative affect, the coefficient was 0.83 for the total, while for the experimental group it was 0.80, and for the control group 0.84. In this research, Cronbach's alpha coefficient ranges from 0.93 for the total sample, that is, 0.92 for the experimental group of handball players and 0.93 for the control group.

To test the hypotheses, three t-tests were made and the results are shown in Table 1.

Table 1. t-test and Cohen's D, variables satisfaction with life, positive and negative affect with regard to kinesiological activity handball.

Variable	Group	M	SD	t-test	Significance	Cohens' d
Life satisfaction scale	E	82.54	11.79			
	C	75.02	14.29			0.55
	Total	79.07	13.52	7.93	.00	
Positive affect	E	4.71	1.06			
	C	4.24	1.10			0.42
	Total	4.49	1.11	6.07	.00	
Negative affect	E	2.82	1.03			
	C	3.37	1.17			0.48
	Total	3.08	1.14	-6.95	.00	

Note. E – experimental group, C – control group.

Statistically, significant differences are shown in Table 3. Adolescent handball players differ in all measured variables from adolescents who do not train (control groups). Adolescent handball players have higher results on the life satisfaction scale, positive affect, and lower scores on negative affect.

DISCUSSION

The physical activity of adolescents is the subject of numerous studies because regular physical activity is associated with changes in the mental and physical condition of the organism, social actions, and interactions. Research among adolescents often highlights the importance of physical activity and subjective well-being. General findings of many studies indicate the positive effect of physical activity on many segments of life and the organism. E.g., a study of just over 2,000 adolescents in Spain found that more life-satisfied individuals with higher levels of self-efficacy were found among physically active adolescents and a positive correlation was demonstrated among these constructs (Reigal Garrido et al., 2014).

These researchers also found that adolescents who choose sports activities as a form of leisure show higher levels of subjective well-being than those who are not involved in any form of sports activities (Guddal Hjelle et al., 2019; Hung Chen, 2013). In this study, a statistically significant difference was found between the observed groups in terms of life satisfaction and negative and positive effects. Adolescent handball players are more satisfied with life globally and show higher levels of subjective well-being than adolescents who are not involved in any form of sports activity. The levels of affect they demonstrate also differ significantly from those expressed by adolescents who are not involved in any form of regular physical activity. Differences in subjective well-being and levels of life satisfaction depend on different intensities and durations of physical activity (Smedegaard, Christiansen, Lund-Cramer, Bredahl & Skovgaard 2016; Groffik, Mitáš, Jakubec, Svozil & Frömel 2020; Chmelik et al., 2021). Handball is considered an intense physical activity because it is a sport with frequent intense contact, and frequent changes in speed, direction, and rhythm of movement. Numerous muscle groups are activated with a high intensity of load during a very intense and dynamic kinesiological activity. Costigan et al., (2019) in their study of the relationship between physical activity intensity and subjective well-being of adolescents found that moderate and mild physical activity does not contribute to positive affect levels, while intense physical activity found this relationship.

The dimension of social interaction with teammates and the coach can be viewed as another explanation of the relationship between positive influences on subjective well-being such as socializing and supporting teammates. It is also hypothesized that due to changes in well-being associated with physical activity, improvements in self-regulation, sleep quality, and coping skills can be indirectly expected (Morgan, Young, Smith, & Lubans 2016). Handball training, as well as matches, are activities with a longer duration and high levels of workload, and due to this fact, it can be concluded that involvement in handball can contribute to strengthening subjective well-being.

By testing the difference in subjective well-being between adolescent handball players and the control group, statistically, significant differences were found. In all three measured dimensions of subjective well-being, adolescent handball players differ significantly from those who are not physically active. Although adolescents are on average satisfied with life, this study confirmed significant differences between those who train in handball and those who do not engage in any kinesiological activity. The obtained data are interesting and confirm the knowledge that physical activity, in this case, handball has a positive effect on the levels of positive and negative emotions and life satisfaction, that is on subjective well-being that has a significant effect on future mental and physical health (Diener, Pressman, Hunter & Delgadillo-Chase 2017).

CONCLUSIONS

This research confirmed the knowledge about the importance of including adolescents in regular kinesiological activity. Significant differences were found in favour of handball players in every construct of subjective well-being. The data oblige us to think about ways of implementing and increasing the availability of the organized physical activity.

AUTHOR CONTRIBUTIONS

M. L. contributed to the study design and its implementation, formulation of the hypothesis, and data collection. D. B. contributed to the study design and data analysis. Both authors M. L. and D. B. contributed to the final version of the manuscript. I. P. contributed to the study design and supervised the project.

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ORIGINAL ARTICLE

Minimal force to move the heavier opponent: Investigation of sumo game

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ABSTRACT

In sports and daily life, we often experience situations where we should carry an object by pushing it. In this study, we analyse sumo, a Japanese traditional sport, in which one can be a winner by pushing the opponent to the outside of dohyo, the wrestling ring. The optimal strategy for the lighter wrestler to carry the heavier opponent by sliding on dohyo is explored in terms of physics. Although the lighter wrestler can never slide the opponent by pushing forward, this can be achieved by exerting the force diagonally upward. As a result of analysis, we obtain the magnitude and direction of the force that should be applied to initiate the sliding motion and ensure its fastest movement. The result reveals the existence of a critical weight ratio of the wrestlers; if the ratio is upper than a certain value, the lighter wrestler should push to a specific direction, while otherwise the optimal force direction depends on the weight. Due to the generality of physics and mathematics, the application is not limited to sumo; the result provides the most effective way to carry an object on a floor in all activities in sports, exercises, and daily life.
Keywords: Performance analysis of sport, Biomechanics, Theory, Sumo, Game analysis, Optimal strategy.

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INTRODUCTION

In sports as well as daily life, we often have to carry a heavy object by sliding on a floor. Then, we can have a question: what is the most effective way to achieve it? How strongly and in which direction should we push the object? We find such a situation typically in sumo, a Japanese traditional sport. In the game of sumo, two wrestlers fight inside of a 4.55 m circle on a clay platform, namely, *dohyo*. If a wrestler steps outside of the circle, the wrestler is declared the loser. Therefore, one of the ways to be a winner is to push the opponent strongly, make the opponent slide on the *dohyo*, and successfully push the opponent out of the circle. In this study, by applying the laws of physics, we explore the force required to make the opponent slide.

In general, to slide an object on a plane surface, we must apply a force that exceeds the friction between the object and the surface. Regarding friction, it is known that the maximum friction force arising in a static object, referred to as the limiting static friction F_0, is proportional to the force perpendicular to the plane, referred to as the normal force N , that is, $F_0 = \mu_s N$, where the proportionality constant μ_s is referred to as the static friction coefficient (Halliday et al., 2013).

Assume two sumo wrestlers, A and B, have a bout, and A is lighter than B. Then, as evident in the following image, the lighter wrestler A cannot make the heavier opponent B slide if A simply pushes B forward.

The weights of A and B are set to w and W, respectively. Since A is lighter than B, they satisfy $w < \mathrm{W}$. With regards the forces in the vertical direction, the weights on A and B are, respectively, balanced with the normal forces applied by *dohyo*, N_A, and N_B, i.e., $N_A = w$ and $N_B = W$. Hence, their limiting static frictions, F_{0A} and F_{0B}, are given by $F_{0A} = \mu_s w$ and $F_{0A} = \mu_s W$, and therefore $F_{0A} < F_{0B}$ is satisfied, indicating that the limiting static frictions for A is smaller than that for B.

If A pushes B horizontally with a force of the magnitude f (Figure 1a), according tothe Newton's third law, namely, the action-reaction law, A is simultaneously pushed by B with an equal and opposite force (Halliday et al., 2013). Therefore, while A increases the force magnitude f, f exceeds F_{0A} before f exceeds F_{0B}, which indicates that A must begin to slide on *dohyo* before B begins to slide.

However, if A pushes B diagonally upward (Figure 1b), as described in the following sections, it is possible that the limiting static force of A becomes larger than that of B because the normal force on B reduces while that on A increases, and therefore there is a possibility that A can make B slide without sliding backward.

In this study, we investigate the settings under which a lighter wrestler can push a heavier wrestler; in other words, how a light wrestler can strategically push a heavier opponent in a sumo game. Due to the advantage in generality of physics and mathematics, the result would be able to be applied not only to sumo games but also to other various situations in sports as well as in life in carrying a heavy object on a floor. Note that, to avoid the complexity of the discussion, the rotation of the wrestler's body is out of the scope of this study. The rotational motion can be separated from the sliding motion in terms of mechanics and would be independently investigated in another study.

MATERIAL AND METHODS

Model

We consider a situation in which the lighter wrestler A pushes the heavier wrestler B diagonally upward. We set the vertical and horizontal component of the force to be $f_\perp$ and $f_\parallel$, respectively (Figure 1b).

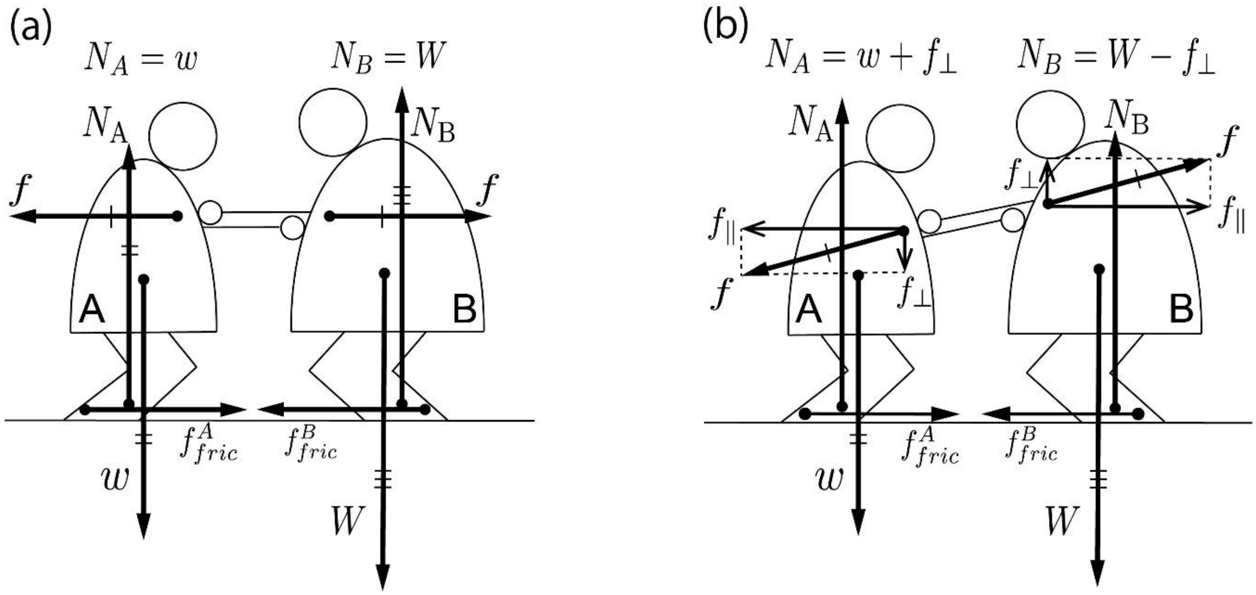

Figure 1. Forces exerted upon the two wrestlers in sumo when the lighter wrestler A pushes the heavier opponent B with a force magnitude f. (a) Case in which A pushes B in the horizontal direction. (b) Case in which A pushes B in a diagonally upward direction.

According to the action-reaction law, the reaction force is generated diagonally downward. Because the magnitude of the vertical component of the reaction force is also $f_\perp$, the normal forces on A and B are:

$$N_A = w + f_\perp, \quad (1)$$
$$N_B = W - f_\perp, \quad (2)$$

which comes from the force balances on A and B in the vertical direction. Therefore, the condition that A can make B slide without sliding backward, namely $F_{0A}(= \mu_s N_A) > F_{0B}(= \mu_s N_B)$ for the limiting static friction, is given by:

$$\mu_s(w + f_\perp) > \mu_s(W - f_\perp), \quad (3)$$

which leads to:

$$f_\perp > \frac{W - w}{2} \quad (4)$$

For A to slide B, another condition must be satisfied; it is necessary that the horizontal component of the force applied to B, $f_\parallel$, exceeds the limiting static friction, $F_{0B}(= \mu_s N_B)$. In other words, according to (2), the relation,

$$f_\parallel > \mu_s(W - f_\perp), \quad (5)$$

must be satisfied.

Thus, the conditions under which the lighter wrestler A can make the heavier opponent B slide are given by the inequalities, (4) and (5). Figure 2a and 2b depicts the region satisfying the relations (4) and (5). If A pushes B with the force represented by points in the shaded region in those figures, B begins to slide without A sliding backward.

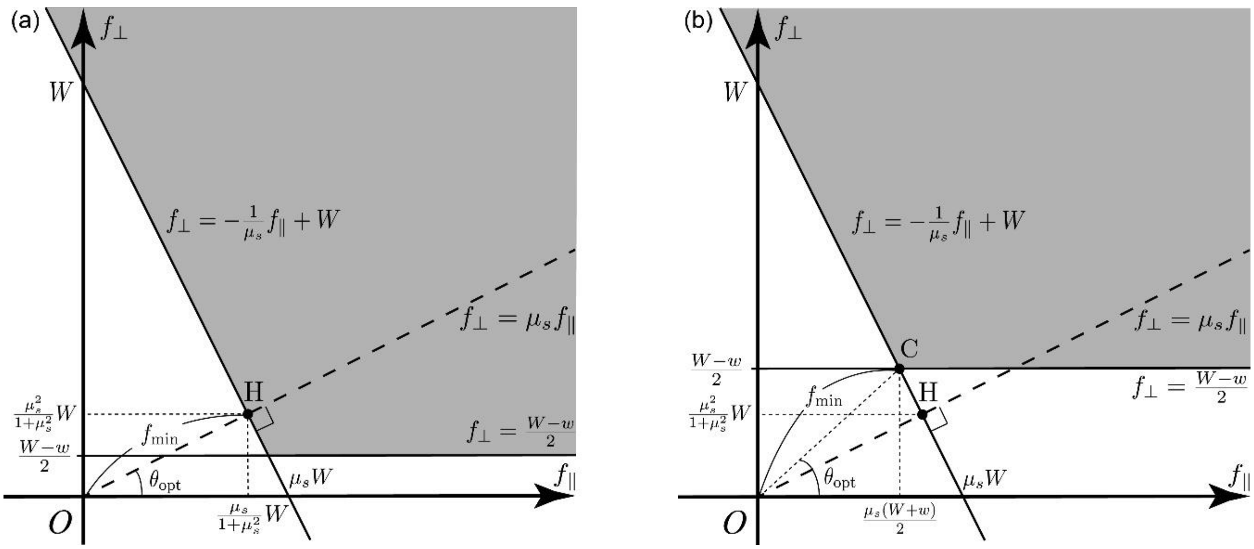

Figure 2. The range in which the lighter sumo wrestler A can make the heavier opponent B slide without sliding backward. (a) When the lighter wrestler is sufficiently heavy ($w \geq \frac{1-\mu_s^2}{1+\mu_s^2} W$), the minimal force required to slide B is represented by point H. (b) When the lighter wrestler is not sufficiently heavy ($w < \frac{1-\mu_s^2}{1+\mu_s^2} W$), the minimal force required to slide B is represented by point C.

RESULTS

Minimal force for sliding

Let us find the minimum magnitude of force, $f_{\min}$, required for A to slide B. Let the angle between the horizon and the force direction be θ_{opt} when the force is exerted. The minimal force is graphically represented by the point whose distance from the origin has the minimum value in the shaded region in Figure 2. Then, there are qualitatively different two cases corresponding to Figure 2a and Figure 2b.

In the first case (Figure 2a), the point H, the foot perpendicular from the origin to the line $f_\parallel = \mu_s (W - f_\perp)$, that is,

$$f_\perp = -\frac{1}{\mu_s} f_\parallel + W, \quad (6)$$

is included in the boundary of the shaded region. In this case, the force corresponding to H is the minimal force. In the second case (Figure 2b), the point H is not included in the boundary of the shaded region. In this case, the force represented by the point C is the minimal force.

Let us analyse the first case. Because the line perpendicular to the line (6) and passing through the origin is represented by:

$$f_{\perp} = \mu_s f_{\parallel}, \quad (7)$$

the coordinates of H are:

$$f_{\perp} = \frac{\mu_s^2}{1+\mu_s^2} W, \quad (8)$$
$$f_{\parallel} = \frac{\mu_s}{1+\mu_s^2} W \quad (9)$$

Therefore, point H is located on the boundary of the shaded region in Figure 2 (i.e., the first case occurs) when:

$$\frac{\mu_s^2}{1+\mu_s^2} W \geq \frac{W-w}{2}, \quad (10)$$

in other words, when the ratio of the weights satisfies:

$$\frac{w}{W} \geq \frac{1-\mu_s^2}{1+\mu_s^2} \quad (11)$$

In this case, the force H in Figure 2a is the minimal force. Then, its magnitude $f_{\min}$ is given by:

$$f_{\min} = \sqrt{f_{\perp}^2 + f_{\parallel}^2} = \frac{\mu_s}{\sqrt{1+\mu_s^2}} W \quad (12)$$

The direction of the force is given by θ_{opt} in Figure 2a, which is determined from the relation,

$$\tan\theta_{\text{opt}} = \frac{f_{\perp}}{f_{\parallel}} = \mu_s \quad (13)$$

Let us analyse the second case, in which the condition (11) is not satisfied, i.e.:

$$\frac{w}{W} < \frac{1-\mu_s^2}{1+\mu_s^2} \quad (14)$$

Then, the minimal force is represented by point C in Figure 2b, which is the intersection of the line (6) and the line:

$$f_{\perp} = \frac{W-w}{2} \quad (15)$$

By substituting Equation (15) into Equation (6), we obtain:

$$f_{\parallel} = \frac{\mu_s(W + w)}{2} \tag{16}$$

at point C. Hence, the magnitude of the minimal force $f_{\min}$ is given by:

$$\begin{aligned} f_{\min} &= \sqrt{f_{\perp}^2 + f_{\parallel}^2} \\ &= \frac{\sqrt{(1 - \frac{w}{W})^2 + \mu_s^2(1 + \frac{w}{W})^2}}{2} W \end{aligned} \tag{17}$$

The direction of the force is given by the angle θ_{opt} in Figure 2b, which is deter- mined from:

$$\begin{aligned} \tan\theta_{\text{opt}} &= \frac{f_{\perp}}{f_{\parallel}} \\ &= \frac{W - w}{\mu_s(W + w)} \end{aligned} \tag{18}$$

Range of the force direction

Assuming that the lighter wrestler A can produce a strong force f_0 that sufficiently exceeds $f_{\min}$, let us find the force direction in which A can make the heavier opponent B slide.

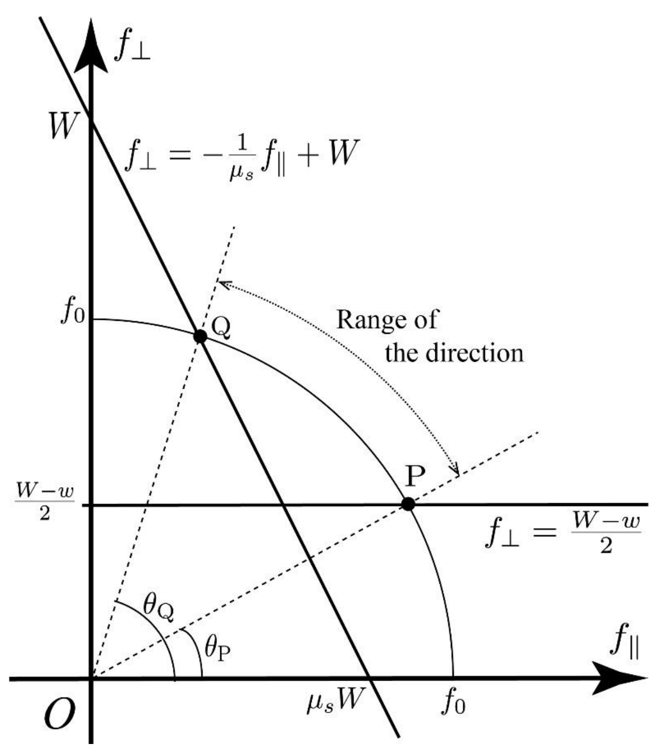

Figure 3. The range of the force direction in which the lighter wrestler can make the heavier opponent slide when the lighter wrestler pushes with a force of magnitude f_0 that exceeds $f_{\min}$

The direction range is represented by $\theta_P < \theta < \theta_Q$ in Figure 3. Point P is the intersection of the line (15) and a circle with centre at the origin and radius f_0. Point Q is the intersection of the line (6) and the same circle. When A pushes in a direction in this range, it is possible to slide B without sliding backward.

Let us calculate θ_P and θ_Q. At the point P, since:

$$f_0 \sin\theta_{\mathrm{P}} = \frac{W - w}{2} \tag{19}$$

holds according to Equation (15), θ_P is given by:

$$\theta_{\mathrm{P}} = \arcsin\frac{W - w}{2f_0} \tag{20}$$

At the point Q,

$$f_0 \sin\theta_{\mathrm{Q}} = -\frac{1}{\mu_s} f_0 \cos\theta_Q + W \tag{21}$$

holds according to Equation (6). By transforming Equation (21), we obtain:

$$\cos(\theta_{\mathrm{Q}} - \phi) = \frac{\mu_s W}{\sqrt{1 + \mu_s^2} f_0}, \tag{22}$$

where ϕ is defined by $\tan\phi = \mu_s$, which corresponds to θ_{opt} in Figure 2a. Therefore, θ_{Q} is given by:

$$\theta_{\mathrm{Q}} = \arctan \mu_s + \arccos\left(\frac{\mu_s W}{\sqrt{1 + \mu_s^2} f_0}\right) \tag{23}$$

In summary, when the lighter wrestler A pushes the heavier opponent B with a sufficiently large force of magnitude f_0 [1] exceeding f_{min}, B starts sliding before A slides backward if A pushes B in the direction of:

$$\arcsin\left(\frac{W - w}{2f_0}\right) < \theta < \arctan \mu_s + \arccos\left(\frac{\mu_s W}{\sqrt{1 + \mu_s^2} f_0}\right) \tag{24}$$

Optimal force direction

To end the bout swiftly, one of the best strategies is to make the opponent move as fast as possible. To achieve this, the acceleration of the opponent should be maximized. Here, we consider the case in which the lighter wrestler A can produce a force of magnitude f_0 (which is supposed to be larger than f_{min}), and find the optimal force direction θ'_{opt} that generates the maximum acceleration in the heavier opponent B.

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[1] Here, the reason for the use of "sufficiently" is, to be strict, in the case that Equation (11) is satisfied and the circle with radius f_0 intersects twice with the line $f_\perp = -f_\parallel/\mu_s + W$, and the range of θ is modified to:

$$arctan\,\mu_s - arccos\left(\mu_s W/\left(f_0\sqrt{1 + \mu_s^2}\right)\right) < \theta < arctan\,\mu_s + arccos\left(\mu_s W/\left(f_0\sqrt{1 + \mu_s^2}\right)\right)$$

In general, according to the Newton's second law, the acceleration of an object is determined using the equation of motion, $ma = f$, where m and f denote the mass of the object and the force acting on the object, respectively. In addition, it is known that the friction force exerted on a moving object is proportional to the normal force N, in the same way as the limiting static friction, and expressed as $\mu_{\mathrm{k}}N$, where μ_{k} is referred to as the kinetic friction coefficient [Halliday et al. (2013)].

In the situation we consider here, because the force acting horizontally on the wrestler B is $f_{\parallel} - \mu_k N_B$, the equation of motion is given by:

$$m_{\mathrm{B}}a_{\mathrm{B}} = f_{\parallel} - \mu_k N_{\mathrm{B}} \quad (25)$$

where m_{B} and a_{B} denote the mass and acceleration of B, respectively. According to Equation (2), Equation (25) is reduced to:

$$m_{\mathrm{B}}a_{\mathrm{B}} = f_{\parallel} - \mu_k(\mathrm{W} - f_{\perp}) \quad (26)$$

Assuming B is pushed by A with a force magnitude f_0 and force direction θ, then, since $f_{\perp} = f_0 \sin\theta$ and $f_{\parallel} = f_0 \cos\theta$, Equation (26) leads to:

$$m_{\mathrm{B}}a_{\mathrm{B}} = f_0\cos\theta - \mu_k(W - f_0\sin\theta), \quad (27)$$

which is reduced to:

$$m_{\mathrm{B}}a_{\mathrm{B}} = f_0(\cos\theta + \mu_k\sin\theta) - \mu_k W \quad (28)$$
$$= f_0\sqrt{1+\mu_s^2}\cos(\theta - \phi') - \mu_k W, \quad (29)$$

where ϕ' is the angle satisfying $\tan\phi' = \mu_k$.

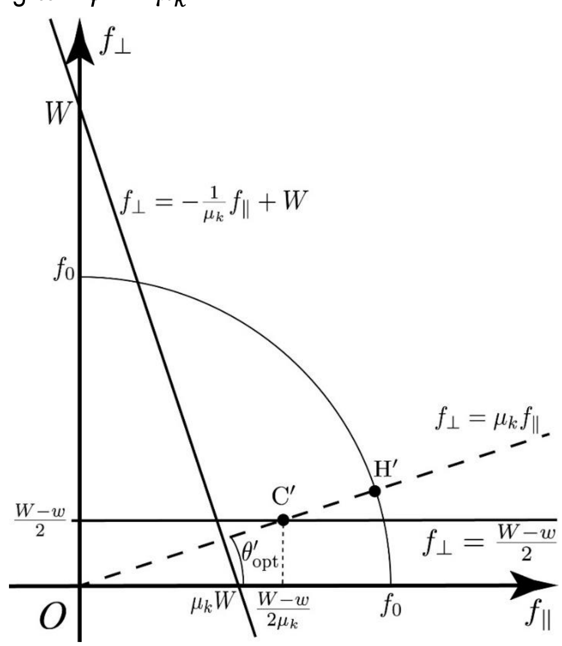

Figure 4. The direction to make the opponent move fastest θ'_{opt}.

Then, the optimal direction $\theta'_{\rm opt}$ is the direction that maximizes the right-hand side of Equation (29). Therefore, we obtain $\theta'_{\rm opt} = \phi'$, which is equivalent to the relation,

$$\tan\theta'_{\rm opt} = \mu_k \quad (30)$$

Hence, if the wrestler A pushes B with the force represented by the point H' in Figure 4, the wrestler A can make B move fastest.

However, also in this case, the vertical component of the applied force must satisfy Equation (4). In other words, the vertical component $f_\perp = f_0 \sin\theta'_{\rm opt}$ must exceed $(\mathrm{W} - \mathrm{w})/2$. Graphically, this case occurs when the force magnitude f_0 exceeds that of C' in Figure 4. In other words, when W and w satisfy the relation:

$$f_0 \geq \sqrt{\left(\frac{W-w}{2}\right)^2 + \left(\frac{W-w}{2\mu_k}\right)^2} \quad (31)$$

$$= \frac{\sqrt{1+\mu_k^2}}{2\mu_k}(W-w) \quad (32)$$

If the lighter wrestler A cannot produce a force that satisfies Equation (32), namely, if:

$$f_0 < \frac{\sqrt{1+\mu_k^2}}{2\mu_k}(W-w), \quad (32)$$

the optimal direction $\theta'_{\rm opt}$ is such that $f_\perp = (W-w)/2$ holds, which is equivalent to the relation:

$$\sin\theta'_{\rm opt} = \frac{W-w}{2f_0} \quad (32)$$

Note that this angle corresponds to the lower limit of (24).

DISCUSSION

Parameter values

Let us numerically estimate the magnitudes and directions of force obtained above by using the parameter values.

Although the static friction coefficient μ_s between clay, which forms dohyo, and the foot has never been measured to the best of the author's knowledge, we assume it at $\mu_s = 0.4$ according to a report that the static friction coefficients between the human skin and various materials mostly have a value between $0.2 - 0.5$ (Sivamani et al., 2003), and the fact that the value between silicon rubber and sand is less than 0.6 (Tay et al., 2015).

While the kinetic friction coefficient μ_k also seems to have never been measured, we assume it to be $\mu_k = 0.3$ because the kinetic friction coefficients are usually smaller than the static friction coefficients (Halliday et al., 2013).

In addition, when we need to give a value of the weight of the heavier wrestler in the following, we set it at $W = 150$ kgw as a typical value of sumo wrestlers.

Minimal force for sliding

The magnitude and direction of the minimal force to slide the heavier wrestler are as follows. They qualitatively depend on whether the ratio of the weights of the two wrestlers is large or small; specifically, w/W is larger or smaller than $(1-\mu_s^2)/(1+\mu_s^2) \sim 0.72$ according to the inequalities (11) and (14). For example, when the heavier wrestler's weight is $W = 150$ kgw, it depends on whether the lighter wrestler's weight is grater or smaller than $w = 108$ kgw.

When the weight of the lighter wrestler is sufficient to satisfy $w \geq 108$ kgw, the minimum force magnitude is estimated from Equation (12), which does not depend on the weight of the lighter wrester, w, and we obtain $f_{\min} = \frac{\mu_s W}{\sqrt{1+\mu_s^2}} \sim 56$ kgw. If the lighter wrestler pushes with the force stronger than this value in the direction determined from Equation (13), which is estimated as $\theta_{\text{opt}} = \arctan \mu_s = \arctan 0.4 \sim 22^{\circ}$, the wrestler can slide the heavier opponent.

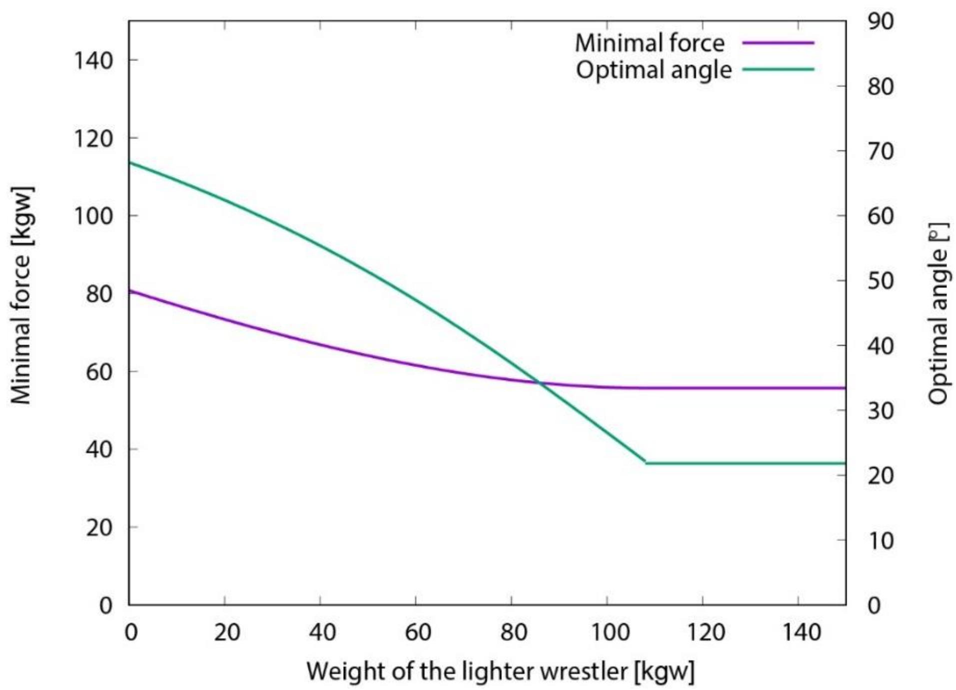

Figure 5. The magnitude and direction of the minimal force for various weights of the lighter wrestler under $\mu_s = 0.4$ and $W = 150$ kgw.

Conversely, when the lighter wrestler is so light that $w < 108$ kgw is satisfied, the minimum magnitude of force is estimated from Equation (17), which depends on the weight of the wrestler w. For example, when

$w = 90$ kgw, the heavier wrestler can slide when the lighter wrestler pushes with a force stronger than $f_{\min} = \frac{W\sqrt{\left(1-\frac{w}{W}\right)^2 + \mu_s\left(1+\frac{w}{W}\right)^2}}{2} \sim 57$ kgw in the direction determined by Equation (18), which is estimated as $\theta_{\text{opt}} = \arctan((W - w)/[\mu_s(W + w)]) \sim 32^{\circ}$.

Figure 5 illustrates the $f_{\min}$ and θ_{opt} for various weights of the lighter wrestler, w.

Range of the force direction

When the lighter wrestler can exert a strong force that sufficiently exceeds $f_{\min}$, various force directions can possibly make the heavier opponent slide. The range of the force direction is given by Equation (24). For example, when the weights of the heavier and lighter wrestler are $W = 150$ kgw and $w = 90$ kgw, respectively, and if the lighter wrestler can generate a force of magnitude $f_0 = 80$ kgw, the lower limit of the angle of the direction is $\arcsin((W - w)/(2f_0)) \sim 22^{\circ}$, and the upper limit is $\arctan \mu_s + \arccos(\mu_s W/[(\sqrt{1 + \mu_s^2}) f_0]) \sim 68^{\circ}$.

Figure 6 presents the relation between the force magnitude and the range of the force direction in which the heavier wrestler will slide.

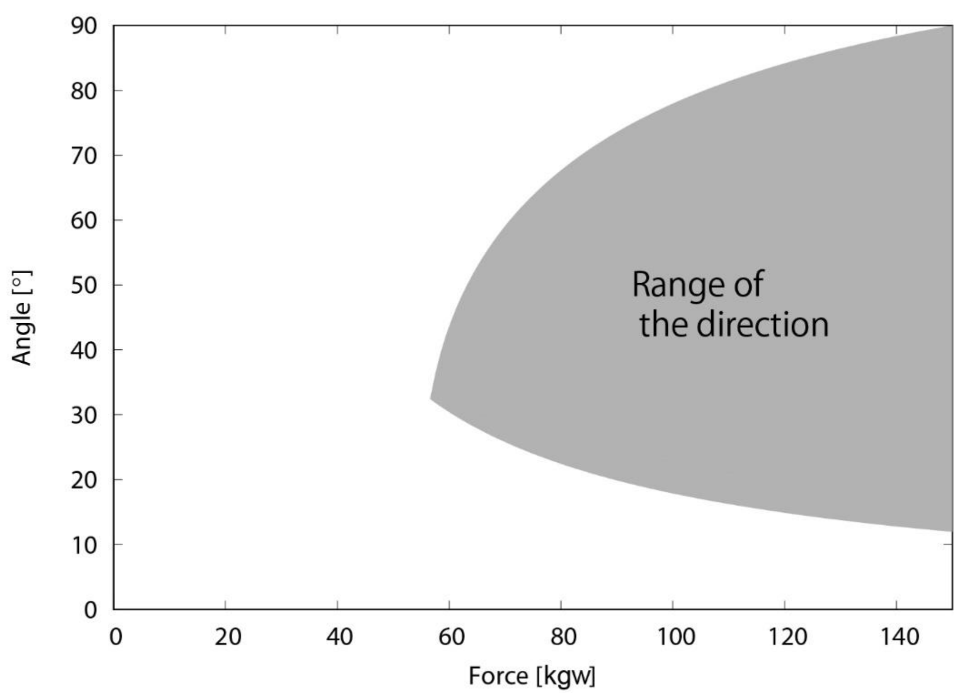

Figure 6. The force direction in which the heavier wrestler slides for various force magnitudes under $\mu_s = 0.4$, $W = 150$ kgw and $w = 90$ kgw.

Optimal force direction

Let us estimate the optimal force direction in which the lighter wrestler can make the heavier opponent move as fast as possible. The optimal force direction qualitatively depends on whether the magnitude of the force produced by the lighter wrestler exceeds $f_0 = \frac{(W-w)\sqrt{1+\mu_s^2}}{2\mu_s} \sim 52$ kgw (when $W = 150$ kgw, $w = 120$ kgw) (Equations (32) and (33)).

When the applied force magnitude f_0 is greater than 52 kgw, the optimal force direction is determined from Equation (30), that is, $\tan\theta'_{\text{opt}} = \mu_k = 0.3$, which does not depend on the force magnitude f_0. Hence, the optimal way is to push in the direction of $\theta'_{\text{opt}} = \arctan 0.3 \sim 17^{\circ}$.

On the other hand, when the force that can be produced is less than 52 kgw, optimal force direction is determined from (34), and depends on the force magnitude f_0. For example, when $f_0 = 40$ kgw, the optimal force direction is calculated usingsin $\theta'_{\text{opt}} = (W - w)/(2f_0) \sim 0.38$. In other words, the optimal method is to push in the direction of $\theta'_{\text{opt}} = \arcsin 0.38 \sim 22^{\circ}$.

Figure 7 depicts the optimal direction for various pushing forces in the case that the heavier wrestler's weight is $W = 150$ kgw and lighter's one is $w = 120$ kgw.

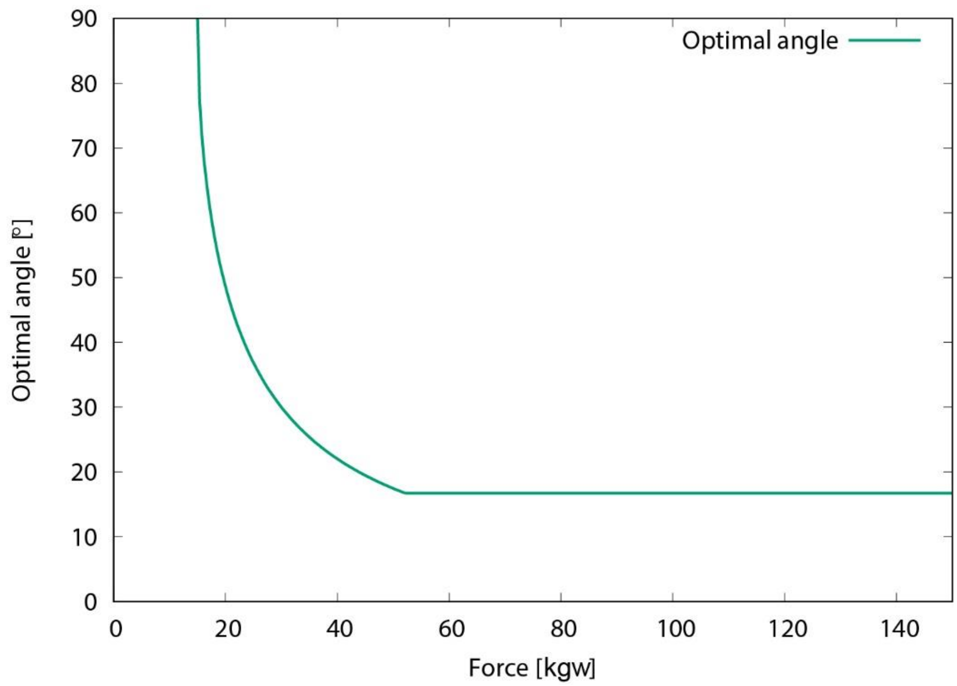

Figure 7. The optimal force direction, in which the maximum acceleration is generated in the opponent, for various force magnitudes under $\mu_k = 0.3$, $W = 150$ kgw and $w = 120$ kgw.

CONCLUSIONS

In conclusion, mathematical formulae providing the best strategy for the lighter wrestler to win a sumo game by pushing the heavier opponent on dohyo as fast as possible is suggested as follows.

In sumo, the actual process is such that the magnitude of force increases gradually from 0 even if it occurs in a moment. Therefore, to initiate sliding the heavier opponent, the lighter wrestler should push in the direction of the minimal force. The direction of the minimal force depends on the ratio of the weights of the two wrestlers w/W. If the lighter wrestler is sufficiently heavy as $(1-\mu_s^2)/(1+\mu_s^2) < w/W$ (Equation (11)), the wrestler should push in the direction of $\theta = \arctan \mu_s$ (Equation (13)). In this case, the minimum requirement for the force magnitude is $\mu_s/\sqrt{1+\mu_s^2}$ times the heavier wrestler's weight (Equation (12)). If the lighter wrestler is so light that $w/W \leq (1-\mu_s^2)/(1+\mu_s^2)$ ((Equation (14)) is satisfied, the wrestler should push in the direction of $\theta = \arctan((W-w)/[\mu_s(W+w)])$ (Equation (18)). In this case, the minimum requirement for the force magnitude is $\sqrt{(1-w/W)^2+\mu_s(1+w/W)^2}/2$ times the heavier wrestler's weight (Equation (17)).

Once the opponent starts to slide, it is ideal for the lighter wrestler to make the opponent move as swiftly as possible. When a lighter wrester can generate a force magnitude exceeding $(W-w)\sqrt{1+\mu_s^2}/(2\mu_s)$ (Equation (32)), the wrestler should push in the direction of $\theta = \arcsin((W-w)/(2f_0))$ (Equation (33)).

In a real game, the heavier opponent will of course not be static but push the lighter wrestler. Nevertheless, we should note that the above analysis is still effective; all the above results can be derived similarly if we replace the force generated by the lighter wrestler to the sum of the force generated by both the lighter and heavier wrestler in the equations above. Some future studies can be carried out to obtain more realistic predictions. Since the friction coefficient is the key to determine the forces calculated above, measurement of the static and kinetic friction coefficients would be important to find the best strategy for sumo wrestlers. In addition, although it is assumed in this study for simplification that the force magnitude generated by the wrestlers does not depend on the direction, in reality, the available force magnitude would depend on the direction θ, and be a function of the direction, $f(\theta)$. Nevertheless, the logic of the analysis would not be modified; instead of drawing a circle of the radius of f_0 in Figure 3 and Figure 4, we only have to draw the graph of $f(\theta)$, and carry out the analysis in the same manner. To obtain predictions that is more applicable to the real game, measurement of $f(\theta)$ would be meaningful.

Finally we should note that the importance of this study is not limited to sumo; the result can be applied to all situations where we carry an object by sliding on the floor. We can do it most effectively if we push the object to the direction given by Equation (13) or (18) to initiate the sliding, and to the direction given by Equation (30) or (34) after the initiation of the sliding.

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DISCLOSURE STATEMENT

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SCIENTIFIC JOURNAL OF SPORT AND PERFORMANCE

ORIGINAL ARTICLE

Effects of asymmetric trunk muscle fatigue on pelvic inclination and rotation

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ABSTRACT

Although the influence of muscle activity on the pelvic position has been proven, research on the influence of (asymmetric) muscle fatigue on the pelvic position is inconsistent. The purpose of the present study was to assess the effects of asymmetric fatigue of the lateral trunk muscles on the pelvic position based on a pre/post/follow-up design. For the final data analysis, 38 subjects (20 men, 18 women; age 22.63 ± 3.91 years) were asked to perform side bends in sets of 20 repetitions on a Roman chair until complete exhaustion. For pre-, post-, and follow-up test (24 h after treatment), pelvic positions were recorded with a 3D photogrammetric scan. Statistical analysis showed no systematic changes in pelvic inclination and rotation after unilateral exhaustion for the three measuring times. However, highly individual, non-systematic changes in pelvic positions were present, especially between pre- and post-test. The follow-up measurements tend to return to the initial pre-test state. Unilateral fatigue of the lateral flexors of the trunk affects the pelvic position in a non-systematic way.
Keywords: Performance analysis of sport, Physical conditioning, Pelvis, Muscle soreness, Posture, Sport.

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INTRODUCTION

The position of the pelvis in space has a decisive influence on the posture of the trunk. Furthermore, it is the mechanical basis for the spine (Day et al., 1984; Jackson et al., 2000; Le Huec et al., 2011; Stylianides et al., 2013). It is determined by:

- biomechanical (e.g., leg length differences (Betsch et al., 2011; Rhodes & Bishop, 2010)),
- articular (joint status of the sacroiliac joints (Hansen & Helm, 2003; Pel et al., 2008) and the pubic symphysis (Leadbetter et al., 2004)),
- and neuromuscular factors (including the status of the trunk, thigh and pelvic floor muscles (Buchtelová et al., 2013; López-Miñarro et al., 2012; Pool-Goudzwaard et al., 2004)).

A significant number of pathological entities may result from changes in the pelvic position (Jackson et al., 2000; Jentzsch et al., 2013; Roussouly & Pinheiro-Franco, 2011; Volinski et al., 2018). Therefore, investigating possible correlations or influencing factors is of interest for functional understanding and possible therapeutic approaches (Yoo, 2013). Possible differences in static and dynamic pelvic parameters between subjects without symptoms and patients could provide important diagnostic information (Montgomery et al., 2011; Roussouly et al., 2002; Schwab et al., 2006; Smith et al., 2008; Stylianides et al., 2013; Youdas et al., 2000).

Although the influence of muscle activity on the pelvic position has been proven, research on the influence of (asymmetric) muscle fatigue on the pelvic position is inconsistent (Buchtelová et al., 2013). For example, one-sided muscle fatigue can occur in sports with asymmetrical movement sequences and occupational activities with a one-sided trunk alignment. The lateral flexors of the trunk can subsequently cause unilateral pelvic inclination or forward pelvic rotation (ante pulsion) (Buchtelová et al., 2013).

Our research goal for this study was to analyse the pelvic position before and after 24 h of unilateral fatigue of the muscles responsible for lateral flexion of the trunk. We expected a unilateral increase in pelvic rotation or inclination due to unilateral fatigue.

MATERIAL AND METHODS

Participants

Data were collected from a total of 41 healthy subjects. Illness reported pain located in the back area and recent injuries were defined as exclusion criteria. Subjects were advised to come in a rested state and not to perform intense physical activities for 48 h prior to the study. Of the initial 41 subjects, data from 38 subjects (20 men, 18 women; age 22.63 ± 3.91 years; height 173.36 ± 9.95 cm; weight 71.89 ± 12.97 kg; body fat 20.92 ± 9.58 %) were used for the final analysis. The three subjects were excluded because their execution of the exercises was not in accordance with the instructions, or data from one of the three measurement times were missing.

Our study was approved by the ethical committee of the university and met the criteria of the Declaration of Helsinki (Smith et al., 2008). All participants signed an informed consent form, including permission to publish the results of the study. Subjects were asked not to perform intense activities 48 h prior to the study and come in a rested state.

Procedures

The subjects performed side bends on a Roman chair in sets of 20 repetitions to unilateral exhaustion of the lateral flexors of the trunk. The treatment targeted the contralateral side to the handedness side. Previous research showed the effectiveness of the protocol for introducing asymmetric fatigue in the context of side differences in skin surface temperatures (Dindorf et al., 2022). Tactile feedback (contact point to a bar at the endpoint of maximal lateral trunk flexion) was used to control the range of motion (ROM). Upward and downward movement was timed in a standardized way using a metronome. The termination criteria were defined as the following to ensure total exhaustion: a) exertion score of at least 8 on the OMNI Scale (Robertson, 2004); b) inaccurate execution across at least the last five repetitions of a set; c) over 3 sets of the specified number of 20 repetitions could not be achieved; d) ROM could not be completely maintained until the last repetition.

Photogrammetric noncontact 3D scan

Posture was measured using a photogrammetric noncontact 3D scanner (Paromed 4D, Neubeuern, Germany). Upper body clothing was removed for the measurements, and women wore sports bras.

In their habitual posture, the subjects stood barefoot at a distance of 2.5 m from the scanner. Markers were placed on the bony landmarks of C7 and S1, the most concise points of the neck and lumbar lordosis and chest kyphosis, both inferior angles of the scapula and both posterior superior iliac spines. Locations were marked with a water-resistant pen to ensure the same position for the next measuring day. Posture data was recorded three times on two different days: before the treatment (pre), directly after the treatment (post), and approximately 24 h afterward (follow-up).

Questionnaires

Additionally to the above mentioned rating of perceived exertion on the OMNI Scale (Robertson, 2004), the participants specified items from the dimension 'fatigue' of the Profile of Mood States (POMS) questionnaire (McNair et al., 1971) directly and 24 h after the treatment. On Days 2 and 3, delayed-onset muscle soreness (DOMS) was measured using the 7-point Likert scale according to (Priego-Quesada et al., 2020).

Statistical analysis

Repeated measures ANOVA were used to check pelvic position changes for the measurement times. Necessary requirements were checked and could be assumed. All groups were normally distributed according to Kolmogorov-Smirnov test. Greenhouse–Geisser adjustments were made to correct violations of sphericity. Bonferroni correction was performed for post hoc testing. Alpha level of .05 was set as the cut-off for significance. The results are reported as mean and standard deviation. Calculations were performed using SPSS Statistics (version 25, SPSS Inc., Chicago, USA).

RESULTS

On average, participants accomplished 7.27 ± 4.74 sets of lateral flexion until complete exhaustion and reported a score of 8.88 ± 1.01 on the OMNI scale post treatment. DOMS was scored at 3.78 ± 1.33 24 h after treatment and 5.05 ± 1.10 48 h after treatment.

A comparison of the 'fatigue' dimension of POMS using the average summative score showed the highest fatigue on the day of treatment (19.67 ± 7.41) and the lowest 24 h after the treatment (13.20 ± 6.98).

Figure 1. Start and end position of the treatment for introducing unilateral muscle fatigue. Side bends were performed on a Roman chair.

Table 1. Descriptive statistics (mean and standard deviation) of the evaluated pelvic variables in the measured conditions.

Variable	Pre-test	Post-test	Follow-up test
Pelvic inclination	-0.21 ± 2.17°	-0.07 ± 2.04°	-0.33 ± 2.63°
Pelvic rotation	-1.67 ± 2.53°	-1.85 ± 2.48°	-1.99 ± 2.67°

We found no statistically significant difference for pelvic inclination in the different conditions, F (1.49, 55.22) = 0.307, (*p* = .672), n = 38. Similarly, there was no statistically significant difference for pelvic rotation in the different conditions, F (2, 74) = 0.411, (*p* = .664), n = 38. Table 1 presents the mean and standard deviation of the regarded pelvic parameters at pre-, post-, and follow-up condition. Figure 1 shows measurements of five exemplary subjects; differences seem to alter the most from the pre- to the post-test for both pelvic inclination and rotation, albeit inconsistently. Measurements tend to return to the initial pre-test state after 24 hours.

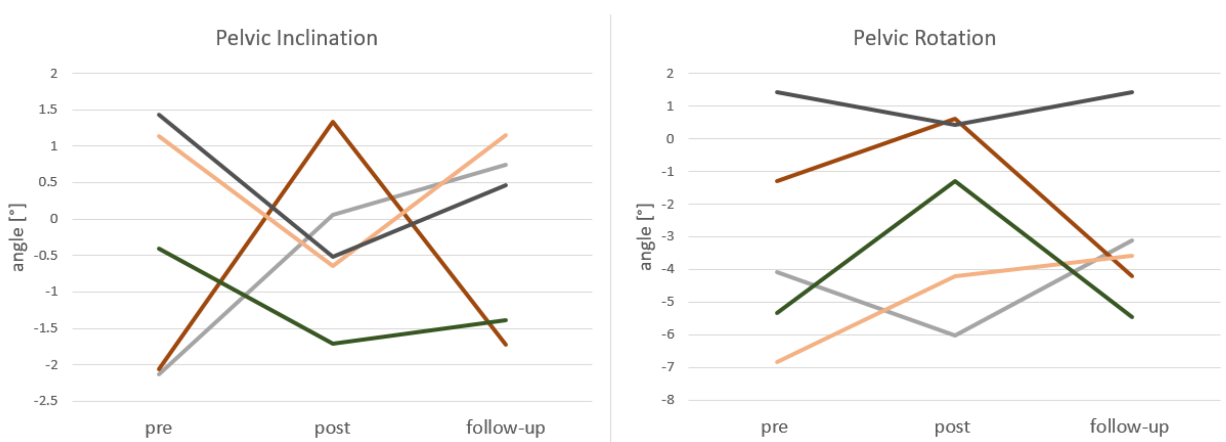

Figure 2. Exemplary measurements for five subjects. Y-Axes: negative values mean inclination or rotation to the left side.

DISCUSSION

The results of the current study did not confirm our hypothesis that pelvic inclination or rotation changes systematically after unilateral exhaustion of the trunk flexor muscles. The results of the DOMS and OMNI tests showed a strong muscular workload with subjective fatigue (POMS) already regenerating the following day. Nevertheless, we found no statistically significant effect on pelvic inclination and rotation after unilateral exhaustion of the trunk flexors. Our study showed that changes in pelvic position were individually different in magnitude and unsystematic in direction.

On the contrary, regarding possible effects of asymmetric muscle fatigue on the pelvic position, gait, and posture (Youdas et al., 1996)showed a relationship between pelvic inclination and shortening of the back muscles but none to the hip flexors. However, it must be noted that existing studies always loaded the investigated muscle groups symmetrically and measured effects only in the sagittal plane (Yoshitake et al., 2001).

Several muscle groups are involved in the lateral flexion of the trunk. These include the rectus abdominis muscle, the obliquus internus abdominis muscle, and the quadratus lumborum muscle. The transversus abdominis muscle also contributes a rotatory component and may have been partly responsible for unilateral pelvic rotation (Schünke et al., 2022; Stokes et al., 2011; Thelen et al., 1995). Different initial muscular states (in terms of strength endurance), as well as different motor control strategies, maybe the cause of the individual differences found. It is known that in postural stabilization, different individuals show different motor activation patterns (Alvim et al., 2010).

In addition to the large trunk muscles, other muscle groups contribute to lateral flexion (e.g., M. iliocostalis lumborum, M. intertransversarii). These are partly small muscle strands that tire more quickly and may lead to the observed individually different discontinuation of the exercises but unable to influence the pelvic position.

Regarding possible limitations, although the execution of the treatment was constantly controlled and correction instructions were provided, a common mistake was, for example, the rotation of the upper body, which may have led to a shift of muscle activity to smaller, deeper muscles and explained the intraindividual differences (McGill, 2003; Thelen et al., 1995). The general measurement methodology using surface topography shows good results in terms of validity and reliability (Applebaum et al., 2021). Regarding the placement of the markers, their location was marked on the skin with a pen to ensure the same maker positioning for every measuring day. The cause of the unsystematic changes as results of corresponding reliability issues seems, therefore, overall little.

Further research should include more potential influencing factors to explain these highly individual, non-systematic responses better. Possibly, significant changes might be more visible in gait.

CONCLUSION

The inconsistent influences of unilateral trunk muscle fatigue on pelvic position show the complexity and individuality of muscular involvement.

AUTHOR CONTRIBUTIONS

Bartaguiz, Dindorf, conceived and designed the experiments; Bartaguiz, Janowicz performed the experiments; Dindorf and Fröhlich analysed the data; Fröhlich and Ludwig contributed materials/analysis tools; Bartaguiz, Dindorf, Janowicz, Fröhlich and Ludwig wrote the paper.

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The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

ETHICS STATEMENT

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by Technische Universität Kaiserslautern. Informed consent was obtained from all subjects involved in the study.

INFORMED CONSENT STATEMENT

Informed consent was obtained from all subjects involved in the study. Written informed consent was obtained from the patients to publish this paper.

DATA AVAILABILITY STATEMENT

The data are available if there is justified research interest.

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SCIENTIFIC JOURNAL OF SPORT AND PERFORMANCE

ORIGINAL ARTICLE

Effects of an elastomeric technology garment on different external and internal load variables: A pilot study

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ABSTRACT

Resistance training is one key method for improving physical conditioning. With this purpose, Menatechpro System® has designed an avant-garde garment that includes elastomeric technology that may stimulate the neuromuscular system in a better way, but a deeper knowledge of its effects is needed. Objective: To explore the effects of a new garment with elastomeric technology on upper-limb performance, and neuromuscular, perceptual, and cardiovascular responses in two upper-extremities exercises. Methodology: Fit young men trained in resistance exercises performed a seated shoulder press (80% of one-repetition maximum) and push up (bodyweight) until muscle failure with the garment that incorporates the elastomeric technology versus a placebo garment without it. The number of repetitions, mean propulsive velocity, mean and peak muscle activation, rate of perceived effort and perceived velocity, and heart rate were analysed. Possible differences were obtained with a two-way mixed ANOVA of repeated measures with post-hoc analysis. Results: Compared with a placebo garment, the use of this new garment with elastomeric technology improved positively the physical performance and muscular activation during the exercises analysed ($p \leq .05$). Conclusion: Menatechpro System®'s elastomeric technology integrated into the garment could provide an optimal neuromuscular stimulus for the development of the performance during the upper extremity training.

Keywords: Performance analysis of sport, Physical conditioning, Number of repetitions, Mean propulsive velocity, Rate of perceived effort, Velocity perception of execution, Heart rate, Muscle activation.

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INTRODUCTION

Human physical conditioning is determined by a wide range of athletic abilities which include strength and cardiovascular status (Joyner & Dominelli, 2021; Suchomel et al., 2016). From these items, central and peripheral pathways involved in performance and fatigue are explained (Taylor et al., 2016). Accordingly, as exercise training leads to morphological, biochemical, and functional adaptations, training variables may be cautiously selected for maximizing the desired effects (Gene-Morales, Flandez, et al., 2020; Gene-Morales, Gené-Sampedro, et al., 2020; Halson, 2014).

Exercise stimulus is produced through skeletal muscle contraction. In this sense, the inputs and outputs involved in muscle contraction are driven by the nervous system (Alix-Fages et al., 2022). Thus, motor control and force production of each muscle fibre is determined by supraspinal structures, spinal cord, and peripheral skeletal muscle activity (Alix-Fages et al., 2022). Nervous system peripheral function can be measured through the electrical responses of the neuromuscular system with non-invasive tools such as surface electromyography (EMG) (Hermens et al., 2000). Besides, although EMG may provide valuable information concerning the specific mechanisms of muscle contraction, mechanical performance (e.g., kilograms used, repetitions, velocity) may be measured for ensuring a direct relevant outcome on performance. In this regard, previous research has identified a wide variety of outcomes for assessing resistance training such as the mean propulsive velocity (MPV) and velocity loss of a linear movement or the direct force produced against a surface (González-Badillo et al., 2017; Hinshaw et al., 2018).

On the other hand, metabolic factors of performance can be evaluated through the cardiovascular system and the peripheral responses of blood vessels and organelles as mitochondrion (Lee & Zhang, 2021). In this sense, heart rate has been proposed as a predictor of training intensity (Mikus et al., 2009). Moreover, heart rate behaves in a different way in acute and chronic exercise exposures (Reimers et al., 2018). During exercise, athletes suffer a rise in heart rate as a consequence of the need for higher levels of blood perfusion, however, chronic adaptations to endurance training lead to lower basal values, which are correlated with increased lifespan (Reimers et al., 2018).

Of note, these different physiological outcomes can be improved through a wide range of physical exercise modalities and methods (Carlson et al., 2016; Gene-Morales et al., 2022). In recent years elastic materials have been proposed as a plausible tool for enhancing physical abilities due to their inexpensive acquisition, easy portability, and verified results (Gene-Morales, Gené-Sampedro, et al., 2020; Hammami et al., 2022; Saez-Berlanga et al., 2022). Consequently, new devices based on elastomeric technology have been recently created for improving multicomponent elastic training.

Therefore, this study aimed to explore the effects of a new elastomeric garment on upper-limb performance and neuromuscular, perceptual, and cardiovascular responses in the seated shoulder press and push up exercises. It was hypothesized that this new garment may exert a positive impact on all the different analysed variables.

MATERIALS AND METHODS

Participants

Five healthy, trained men (see Table 1) were recruited for this study. Exclusion criteria included any metabolic, cardiovascular, neurological, and/or muscular disorder. The participants signed the informed consent after being informed about the study's aims and procedures. The participants were asked not to consume stimulants (i.e., caffeine) or other ergogenic substances before the experimental session and not to engage in strenuous physical activity 24 hours prior to the session. Additionally, they were encouraged to sleep at least 8 hours the night before data collection.

Table 1. Characterizing values of the participants (n = 5).

Variable	Mean (SD)
Age (years)	24 (2.45)
Height (cm)	183 (0.89)
Body weight (kg)	80.56 (7.27)
Body fat percentage	11.02 (3.46)
Handgrip strength (kg)	52.82 (8.20)
Strength training experience (years)	5.20 (2.17)
Number of training sessions per week	4.00 (0.71)

Procedures

All the procedures were conducted during the morning (i.e., between 9 AM and 2 PM) to avoid diurnal variations in participants' performance (Sundstrup et al., 2012). All measurements were recorded by the same trained researchers. The present study was approved by the Local Research Ethics Committee (H20190325095509) and was in accordance with the tenets of the Declaration of Helsinki.

Each participant participated in a single session that comprised: (i) familiarization and anthropometric measurements; (ii) specific warm-up; (iii) determination of maximum voluntary isometric contraction (MVIC) to normalize EMG values; (iv) determination of 80% of one-repetition maximum (1RM) for the shoulder press; (v) military press at 80% 1RM and push-ups until muscle failure. Both exercises were performed with the elastomeric technology garment (Proadvance, Menatechpro System®, Madrid, Spain) and with the placebo equivalent (same garment without elastomers). Therefore, a total of four conditions were performed by each participant. The order of the conditions was: (i) shoulder press at 80% 1RM with the elastomeric garment; (ii) push-ups to muscle failure with the elastomeric garment; (iii) military press at 80% 1RM with placebo garment; (iv) push-ups to muscle failure with placebo garment. The variables analysed were the number of repetitions, mean propulsive velocity (MPV) of the first and last repetition, rate of perceived exertion (RPE), perceived velocity (RPV) of the first and last repetition, EMG, and heart rate.

At the beginning of the session, weight, body fat percentage (Tanita® model BF-350; Tanita Corpo., Tokyo, Japan; accuracy 0.01 kg), height (Seca T214; Seca Gmbh & Co., Hamburg, Germany; accuracy 0.01 cm), resting heart rate, and maximum handgrip isometric force in the dominant hand (SCACAM-EH10117; Camry Scale, South El Monte, CA, USA) were measured. For the handgrip test, the participants were standing with the back against a wall, elbow extended, and the grip placed at the level of the second phalange. The best of two attempts of 5 seconds was recorded for further analysis. At this point, participants performed a standardized warmup consisting of 5 minutes of joint mobility of the shoulder, elbow, and wrist, as well as two repetitions of abdominal plank for 20 seconds each.

After the warmup, two 5-second MVIC assessments of the shoulder press were performed against an immovably fixed resistance (i.e., Smith machine). Three minutes of rest were allowed between attempts. Verbal feedback was homogeneously given to all the participants. The position for the MVIC test was chosen according to standardized procedures (i.e., approximately 90º of shoulder and elbow flexion; Calatayud et al., 2014). To ensure reliability between participants and measurements, EMG data were normalized as the average of the central second in the best of the two attempts performed (Hermens et al., 2000).

Thereafter, two attempts to estimate the load of 80% 1RM for the shoulder press were carried out based on the mean propulsive velocity (MPV) (see García-Ramos et al., [2021] for further information). A velocity of 0.52 m/s determines the load of 80% 1RM in this exercise (García-Ramos et al., 2021). Both attempts were separated by 5 minutes of rest. Two researchers stood at the sides of the Smith machine during the test to assist the participant to return the bar to the support (Calatayud et al., 2014).

After the aforementioned tests, both exercises (i.e., seated shoulder press and push up) were performed with 5 minutes of rest in between. A 10-minute rest was allowed between conditions. To homogenize the speed of movement, an execution tempo of a maximum-speed concentric phase and a 3-second eccentric phase was established for both exercises. The tempo was controlled with a metronome (Ableton Live 6; Ableton AG, Berlin, Germany). The participants received verbal and visual feedback to maintain hand and foot distance and range of motion. The following technique cues were adopted in the shoulder press: (i) an upright seated position with back support, (ii) bent knees, (iii) feet equidistant on the floor, (iv) elbow and shoulder flexed 90º, and (v) standardized biacromial grip width. For the push-ups, according to previous research (Calatayud et al., 2015), each participant (i) started the exercise in an outstretched arms position, (ii) fingers extended, (iii) feet distance fixed according to hips width, and (iv) spine and hips were kept neutral throughout the entire set. The dependent variables (the number of repetitions, MPV, RPE, RPV, EMG, and heart rate) were collected immediately after finishing the set. Additionally, MPV, RPE, and RPV were also collected immediately after performing the first repetition.

Electromyography

To ensure consistency in electrode placement, each participant was shaved and cleaned with a cotton swab moistened with alcohol (Calatayud et al., 2015). Surface electrodes were placed over the clavicular portion of the pectoralis major (PEC); the long head of the triceps brachii (TRI); the anterior deltoid (ADELT); and the upper rectus abdominis (REC) of the dominant side of the body. Surface Electromyography for the Non-Invasive Assessment of Muscles criteria (SENIAM; Hermens et al., 2000) and previous studies in this field (Calatayud et al., 2016, 2017) were followed. Chlorinated silver pre-gelled bipolar surface electrodes (KendallTM Medi-Trace; Coividien, Barcelona, Spain) were placed with an inter-electrode distance of 10 mm. The reference electrode was placed approximately 5 cm from the electrode pair, according to the manufacturer's specifications.

The participants then performed one repetition of the seated shoulder press and a push up to check signal saturation. Two synchronized two-channel handheld devices coupled to a Shimmer branch inertial sensor (Realtime Technologies Ltd; Dublin, Ireland) with 16-bit analog-to-digital (A/D) conversion were employed. The sampling rate was planned at 1024 Hz. One device collected EMG data from the anterior deltoid and long head of the triceps brachii muscles, while the other collected data from the upper rectus abdominis and clavicular bundles of the pectoralis major muscles. The EMG signal was monitored using the validated (Hermens et al., 2000) mDurance software (MDurance Solutions S.L.; Granada, Spain) for Android. All EMG signals were stored on a hard disk for subsequent evaluation. The mDurance software digitally filtered the raw signals automatically using a fourth-order "*Butterworth*" bandpass filter between 20 and 450 Hz. A high-pass cut-off frequency of 20 Hz was employed to reduce any "*artifacts*" that might occur throughout the movement to have a negligible impact on the total power recorded by the EMG (Ferri-Caruana et al., 2022).

Mean propulsive velocity

A linear position transducer (ADR Encoder; ADR, Toledo, Spain) was used to collect the mean propulsive velocity (m/s) of the first and last repetition of each set in the shoulder press at 80% 1RM. The transducer was attached to the bar, allowing the exercise to be performed smoothly and to move vertically (Naclerio et al., 2011). The execution velocity in the push-ups was assessed with a dynamometric platform (Force Decks; Vald Performance, NSW, Australia).

Rate of perceived exertion and velocity

The participants reported global perceived exertion (RPE) and perceived speed values on the first repetition and the last repetition. The OMNI scale of perceived exertion for continuous loads (Robertson et al., 2003) and the speed perception scale ("*Velscale*"; Bautista et al., 2014) were used.

Heart rate

Pre- and post-test heart rate was monitored via a Polar H7 heart rate monitor (Polar Electro Ltd.; Kempele, Finland) linked via Bluetooth to the PolarTeam app version 1.8.5.

Elastomeric garment

To perform the exercises, the participants wore a garment with the Menatechpro System®'s elastomeric technology and a placebo garment without it. Menatechpro System®'s elastomeric technology is sophisticated sportswear that includes the patented system of Menatechpro System® which generates elastic resistance in most planes of motion. The garment with the Menatechpro System®'s elastomeric technology is composed of more than 20 different pieces. Concretely, we used for this study the model "*Pro-advance*" with a final resistance of 8 kilograms. This garment is intended for users and athletes with previous experience in training who want to enhance both their physical performance and the intensity of their resistance training.

Statistical analysis

Statistical analyses were performed using commercial software (SPSS, version 28.0; IBM corp., Armonk, NY, USA). The assumption of normality of the dependent variables was verified with the Shapiro-Wilk test. The level of statistical significance was set at $p < .05$. Results were reported as mean and standard deviation (SD).

A two-way mixed analysis of variance (ANOVA) of repeated measures was used to assess the influence of using or not the technical garment (placebo versus elastomeric technology from Menatechpro System®) and the type of exercise (with external resistance versus body weight) on the number of repetitions performed, mean propulsive velocity, rate of perceived effort of the first and last repetition, rate of perceived velocity of the first and last repetition, heart rate, and mean and peak muscle activation in the anterior deltoid fibres, clavicular fibres of the pectoralis major, and long head of triceps brachii. All the cases complied with Mauchly's sphericity assumption. For the effect size analysis, partial eta squared (n_p^2) was obtained derived from the ANOVA and was interpreted as low (< 0.04), moderate (0.04 – 0.13), and large (> 0.13). Planned pairwise comparisons were conducted using the Least Significant Difference (LSD) correction to evaluate differences.

Aiming at verifying the correlation between variables, Pearson's test was conducted and interpreted as neglectable (≤ 0.19), low (0.20 – 0.39), moderate (0.40 – 0.59), good (0.60 – 0.79), and excellent (≥ 0.80) (Cohen, 2013).

The reliability of the different types of variables was assessed through the intraclass correlation coefficient (ICC). As previously suggested, ICC values were interpreted as poor (< 0.50), moderate (0.50 – 0.75), good (0.75 – 0.90), and excellent (> 0.90) reliability, based on the lower bound 95% confidence interval (Fleiss, 1986).

RESULTS

The ANOVA testing showed that independently of the exercise performed, the use of the elastomeric garment showed significant differences or tendencies compared with the placebo garment in the number of repetitions ($F(1,4) = 3.61$, $p \leq .05$, $n_p^2 = 0.99$), RPE of the first repetition ($F(1,4) = 45.00$, $p \leq .05$, $n_p^2 = 0.92$), mean activation of the ADELT ($F(1,4) = 5.32$, $p = .08$, $n_p^2 = 0.57$) and PEC ($F(1,4) = 8.60$, $p \leq .05$, $n_p^2 = 0.68$), and maximum activation of ADELT ($F(1,4) = 7.83$, $p \leq .05$, $n_p^2 = 0.66$) and TRI ($F(1,4) = 4.69$, $p = .09$, $n_p^2 = 0.54$).

Considering the effects of the type of exercise, it is worth highlighting that the use of the garment showed a tendency of significant differences in the mean activation of the TRI ($F(1,4) = 4.70$, $p = .1$, $n_p^2 = 0.54$).

Finally, the interaction use of the garment * type of exercise showed significant differences or tendencies in the number of repetitions ($F(1,4) = 13.88$, $p \leq .05$, $n_p^2 = 0.78$), mean activation of ADELT ($F(1,4) = 5.74$, $p \leq .05$, $n_p^2 = 0.59$) and PEC ($F(1,4) = 3.20$, $p = .12$, $n_p^2 = 0.44$).

Table 2 presents the results and differences in the external load (number of repetitions and MPV) between using the garment or the placebo to perform both exercises (seated shoulder press and push-ups). On the other hand, Table 3 shows the results and differences in the external load (RPE, RPV, and heart rate). Finally, Table 4 contains the results and differences in the mean and maximum muscle activation of the studied muscles.

Table 2. Comparison of the use of the garment that incorporates the Menatechpro System®'s elastomeric technology versus the placebo garment differentiated by the type of exercise in terms of external load variables.

		Nº reps	%	MPV-1	%	MPV-F	%
Shoulder press	MPS®	5.6 (1.95)	--	0.41 (0.015)	--	0.17 (0.05)	-10.53
	Placebo	5.6 (1.52)		0.41 (0.10)		0.19 (0.06)	
Push-ups	MPS®	23.2 (5.26) *	+19.60	0.58 (0.04)	--	0.17 (0.03)	+13.33
	Placebo	19.4 (4.28)		0.58 (0.03)		0.15 (0.05)	

*Note. The table shows the mean values and in parentheses the standard deviation (n = 5). * Statistically significant difference (p ≤ .05) between the placebo garment and the garment that incorporates the Menatechpro System®'s elastomeric technology. MPS®: Menatechpro System®´s elastomeric technology; Nº reps: Repetitions' number; %: percentage of variation between conditions (elastomeric minus placebo); MPV-1: Mean propulsive velocity of the first repetition; MPV-F: Mean propulsive velocity of the last repetition.*

Table 3. Comparison of the use of the garment that incorporates the Menatechpro System®'s elastomeric technology versus the placebo garment differentiated by the type of exercise in terms of the internal load variables (rate of perceived effort, velocity perception, and heart rate).

		RPE-1	RPE-F	RPV-1	RPV-F	HR-pre	HR-post
Shoulder press	MPS®	6.0 (1.00) *	9.8 (0.45)	2.8 (0.45)	5.0 (0.00)	57.2 (5.80)	167.0 (13.13)
	Placebo	5.4 (1.52)	9.8 (0.45)	3.0 (0.71)	5.0 (0.00)	57.2 (5.80)	163.0 (8.70)
Push-ups	MPS®	2.8 (1.64) *	9.8 (0.45)	1.6 (0.89)	5.0 (0.00)	56.8 (5.89)	155.6 (13.52)
	Placebo	2.6 (1.67)	9.8 (0.45)	1.6 (0.55)	5.0 (0.00)	56.8 (5.89)	155.2 (10.57)

*Note. The table shows the mean values and, in parentheses, the standard deviation (n = 5). * Statistically significant difference (p ≤ .05) between the placebo garment and the garment that incorporates the Menatechpro System®'s elastomeric technology. MPS®: Menatechpro System®´s elastomeric technology; RPE-1: Rate of perceived effort for active muscles in the first repetition (0-10); RPE-F: Rate of perceived effort for active muscles in the last repetition (0-10); RPV-1: Rate of perceived velocity in the first repetition (1: very fast; 2: fast; 3: moderate; 4: slow; 5: very slow); HR-pre: peak heart rate just before the first repetition; HR-post: peak heart rate after the last repetition.*

Table 4. Comparison of the use of the garment that incorporates the Menatechpro System®'s elastomeric technology versus the placebo garment differentiated by the type of exercise in terms of the internal load corresponding to muscle activation.

		Mean muscle activation (μV)					
		Deltoid	%	*Pectoral*	%	*Triceps*	%
Military Press	MPS®	1036.73 * (381.90)	+25.15	631.01 * (328.15)	+33.52	1248.88 * (657.78)	+25.01
	Placebo	828.40 (333.47)		472.61 (192.85)		999.04 (504.05)	
Push-ups	MPS®	679.27 (479.95)	+9.1	344.88 (117.00)	+3.35	644.05 (280.91)	-1.88
	Placebo	622.79 (307.23)		333.70 (76.35)		656.38 (214.92)	

		Peak muscle activation (μV)					
		Deltoid	%	*Pectoral*	%	*Triceps*	%
Military Press	MPS®	126.25 * (32.61)	+18.12	138.27 (15.88)	+11.63	181.72 * (116.51)	+28.86
	Placebo	106.88 (23.16)		123.86 (16.29)		141.02 (97.84)	
Push-ups	MPS®	134.66 (69.83)	+12.20	130.89 (57.99)	+8.90	198.73 (194.16)	+12.88
	Placebo	120.02 (53.65)		120.19 (90.07)		176.05 (165.53)	

*Note. The table shows the mean values and in parentheses the standard deviation (n = 5). * Statistically significant difference (p ≤ .05) between the placebo garment and the garment that incorporates the Menatechpro System®'s elastomeric technology. MPS®: Menatechpro System®´s elastomeric technology; %: percentage difference between conditions.*

Bivariate correlation analyses showed that the participants with higher levels of ADELT mean activation in the shoulder press performed with the Menatechpro System®'s elastomeric garment, also obtained higher levels of mean activation with the placebo garment (r = 0.99, $p \leq .05$). The same correlation regarding the mean activation of the ADELT was observed in the push-ups (r = 0.97, $p \leq .05$). Similarly, the participants with higher activation levels at the shoulder press with the elastomeric garment also obtained greater activation levels in the push-ups with the elastomeric garment (r = 0.93, $p \leq .05$). Additionally, the participants with higher levels of ADELT maximum activation in the shoulder press performed with the Menatechpro System®'s elastomeric garment also obtained higher levels of maximum activation with the placebo garment (r = 0.88, $p \leq .05$). The same correlation regarding the maximum activation of the ADELT was observed in the push-ups (r = 0.99, $p \leq .05$).

The reliability analyses showed good to excellent values in some of the most relevant study variables (number of repetitions: ICC = 0.95, $p \leq .05$; mean activation PEC: ICC = 0.96, $p = .12$; maximum activation PEC: ICC = 0.85, $p = .12$; RPE of the first repetition: ICC = 0.89, $p = .10$; heart rate: ICC = 0.97, $p \leq .05$).

DISCUSSION

The main aim of this study was to explore the effects of a new elastomeric garment on upper-limb performance and neuromuscular, perceptual, and cardiovascular responses in the seated shoulder press and push up exercises. The main finding was that the garment with the Menatechpro System®'s elastomeric technology significantly increased several physical performance parameters compared with the placebo garment. This finding is in line with previous research focused on the effects of training with variable resistance such as elastic bands (Colado et al., 2020; de Oliveira et al., 2017; Suchomel et al., 2018). Hereunder, the effects of using the elastomeric garment on each of the dependent variables are going to be discussed.

First, the number of repetitions and MPV in the seated shoulder press were the same in both conditions (elastomeric garment vs placebo garment). Considering that the Menatechpro System®'s elastomeric technology adds a resistance of approximately 8 kilograms at the end of the range of motion, it is worth highlighting that the participants used a greater resistance without losing volume (number of repetitions) or intensity (in terms of movement speed). In this regard, the greater resistance employed by the participants is reflected in the higher mean and maximum muscular activation obtained when using the garment with the Menatechpro System®'s elastomeric technology compared with the placebo garment. Potential reasons for the differences (and non-differences) in the external load between using the elastomeric garment or the placebo may be that, due to the elongation coefficient (Andersen et al., 2016; Saeterbakken et al., 2016), the extra resistance of the elastomers is progressively being added at the last degrees of the range of motion and not in the "*sticking point*" (see Kompf & Arandjelović [2016] for further information). Therefore, the participants are utilizing a greater resistance during the more biomechanically advantageous phase of the range of motion (Aboodarda et al., 2013). Taken together, the use of the Menatechpro System®'s elastomeric technology could be helping to overcome the biomechanical disadvantages of the locomotor system by adding more resistance in the phases of the range of movement in which the athlete is "*stronger*". Considering this, this elastomeric garment may optimize the neuromuscular response to resistance exercises (Kompf & Arandjelović, 2016). Additionally, and although we have not measured this, systematically repeating this training stimulus may induce greater performance levels compared to traditional resistance training with constant resistance (Soria-Gila et al., 2015).

Regarding the push-ups, the use of the garment with the Menatechpro System®'s elastomeric technology allowed the participants to perform a greater number of repetitions to failure without significant differences in the MPV and EMG values (Aboodarda et al., 2016; Calatayud et al., 2015). These results may be probably caused by the elastomeric properties of the garment (Andersen et al., 2019), which may assist certain movements such as push-ups. Therefore, the elastomeric garment would be enhancing the performance through a greater time under tension and longer efforts (i.e., a greater number of repetitions).

Apart from the positive results obtained with the use of the garment with the Menatechpro System®'s elastomeric technology in terms of the external load (i.e., greater or similar number of repetitions and muscular activation, without modifying the MPV), the RPV and heart rate were also similar between both conditions. Only a significantly higher RPE was reported by the participants in the first repetition of both exercises. As happened in previous research comparing perceived and actual velocity (Babiloni-Lopez et al., 2022), the elastomeric properties of the garment allow the participants to equate the perceived and actual velocity of the first repetition. The nonsignificant differences between conditions in the RPE and RPV of the last repetition and the heart rate may be due to the maximum character of effort achieved in all the sets. Previous research has shown similar cardiovascular responses in front of similar characters of efforts at different intensities (Babiloni-Lopez et al., 2022; Colado et al., 2018). On the other hand, the higher RPE of the first repetition could be probably due to the greater resistance added by the Menatechpro System®'s elastomeric technology. This result is in line with previous research (Bergquist et al., 2018).

Finally, it is worth mentioning that the findings of the present study are limited to the studied variables and the sample size employed. Therefore, future studies with a bigger sample size and comparing athletes with different experience levels, physical fitness, including both sexes, and different exercises are warranted. Additionally, it would be interesting to analyse the potential effects of using other garments that include the Menatechpro System®'s elastomeric technology (i.e., models Progressive or Pro-sport, which provide 6 and 10 kilograms, respectively).

CONCLUSIONS

The findings of the present study are in line with previous research analysing elastic bands (Iversen et al., 2017). The use of the garment with the Menatechpro System®'s elastomeric technology could be providing an optimum neuromuscular stimulus in the training of the upper limb. Menatechpro System®'s elastomeric technology could be adding greater resistance after the sticking point without diminishing the MPV. This would represent a "*better*" stimulus at the end of the concentric phase and the beginning of the eccentric phase (Aboodarda et al., 2013). Additionally, depending on the movement pattern, Menatechpro System®'s elastomeric technology could be assisting during the first part of the concentric phase, increasing the performance until exhaustion (Andersen et al., 2019).

AUTHOR CONTRIBUTIONS

All authors have contributed positively to the research design, data collection, paper writing, and paper revision.

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DISCLOSURE STATEMENT

Dr. Juan C. Colado is a scientific and technical advisor of Menatechpro System® and so are the rest of the authors of the article.

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SCIENTIFIC JOURNAL OF SPORT AND PERFORMANCE

ORIGINAL ARTICLE

New Deconstruct Elliptical sports machine and Elliptical machine: Comparative analysis of muscle functionality and physiological response in low and high intensity training

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ABSTRACT

The objective of this article was to compare different cardiovascular training machines and their effects on the body, as well as to determine their suitability for people with low intensity or high intensity training needs. A total of 8 physically active and healthy male subjects (mean ± standard deviation; age: 28.45 ± 1.75 years; height: 1.84 ± 0.07 m; body weight 76.42 ± 8.62 kg; body mass index: 25.5 ± 2.6) were evaluated through of an incremental exercise test at different intensities on two different machines: Elliptical Domyos 680 (BED) and Deconstruct Elliptical 331-EF (DEC). To compare both machines against the two mentioned training needs, two different protocols were carried out: Low Intensity Protocol (LIP) and High Intensity Protocol (HIP). As the DEC machine is specifically designed to perform several training positions of different intensities, the LIP was performed in one of its low intensity positions and the HIP in four of its high intensity positions. On the contrary, in the BED machine, both the LIP and the HIP were performed in the only position that its design allows. In the LIP the subjects' heart rate (HR) and energy expenditure EE were analysed. In addition, a thermographic analysis was carried out in order to determine the temperature differences reached in the musculature. No significant differences were found in HR and EE ($p < .05$) between the two machines. However, a greater and more progressive activation of the muscles of the upper extremities was observed in the DEC machine. In the HIP, HR and EE were measured, obtaining significant differences ($p < .05$) higher in the DEC machine. Therefore, in our comparison, the Deconstruct Elliptical machine produced more appropriate results for both low and high intensity training compared to the Elliptical machine. These results and the novel nature of the Deconstruct Elliptical raise the need for further studies to better understand this machine.
Keywords: Performance analysis of sport, Physical conditioning, Deconstruct elliptical, Elliptical machine, Muscle functionality, Physiological response.

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INTRODUCTION

In the context of sports performance and rehabilitation, exercise is in constant progress and popularity (Sozen, 2010). Recent developments in technology have made the monitoring of physical parameters accessible at any time and place for any type of user (Lunney et al., 2016). The continuous advances in research have given rise to increasingly sophisticated equipment, machines and application development in order to collect data regarding physiological, kinanthropometric and sports performance (Sozen, 2010; Peart et al., 2019; Muntaner-Mas et al., 2019).

In this sense, multiple current investigations compare different exercise machines in order to obtain information on their involvement in performance and health (Turner et al., 2010; Bouillon et al., 2016; Hummer et al., 2020; Hummer et al., 2021). In various studies that are carried out with different exercise methodologies, numerous effects can be produced at the cardiovascular level (Haskell et al., 2007; Arikan & Revan, 2020), however, there may be differences in the EE depending on the intensity (Brown et al., 2010). The treadmill, bicycle or elliptical are some of the most studied classic machines in the field of research (Hahn et al., 2013; Arikan & Revan, 2020; Filipovic et al., 2021; Reer et al., 2021) such as titration, performance monitoring and physical analysis equipment (Gumming et al., 1978; Montoye, 1982; Bermejo et al., 2019; Octavio et al., 2019; Björkman et al., 2021; Lee & Zhang, 2021).

In previous studies, training on a bicycle or elliptical trainer has been shown to facilitate coordination or improve reciprocal muscle activity (Damiano et al., 2011; Hornby et al., 2012). In fact, not only has its implementation been proposed in the field of sports performance, but it has also been prescribed by health professionals as a low-impact alternative to reduce stress on the joints (Johnston, 2007).

As for training on the elliptical, it provides beneficial effects at the level of the musculoskeletal system and the cardiovascular system (Lu et al., 2007; Huisinga et al., 2011; Petrofsky et al., 2013). This machine promotes a different trajectory of movement when compared to the treadmill or bicycle (Sozen, 2010) and a different muscle recruitment activity (Cheng et al., 2007). That is why it is considered a good alternative to the treadmill and the classic bicycle, since it also allows muscular synchronization between the upper and lower limbs (Chien et al., 2007; Lu et al., 2007; Sozen, 2010). Although it is important to note that the person must be aware during the execution when it comes to involving all the extremities, causing greater global muscle activation (Batté et al., 2003). On the other hand, the elliptical has been successfully included in a multitude of investigations and tests analyzing the HR or the oxygen consumption reached in various protocols (Mercer et al., 2001; Green et al., 2004; Joubert et al., 2011; Ozkaya et al., 2014), in populations with different pathologies and rehabilitation (Jackson et al., 2010; Orekhov et al., 2019; Roxburgh et al., 2021; Ismail, 2022), as well as in the field of athletic performance and recovery (Tan et al., 2014; Martínez Navarro et al., 2021).

Regarding the comparative aspect, its functionality and response with other machines have been verified, obtaining evident improvements in the upper extremities (brachial biceps, brachial triceps, pectoralis major and trapezius) compared to the bicycle or the treadmill measured with electromyography (Sozen, 2010). In addition, it elicited greater benefits in maximal oxygen consumption in sedentary middle-aged men compared to the treadmill (Velmurugan, 2016). Another study analyzed, in different tests, the differences in maximum oxygen consumption and maximum heart rate in the elliptical and treadmill, finding no significant differences, but higher values in HR on the treadmill (Brown et al., 2015). It has also been compared with other activities to analyze muscle functionality and its aerobic involvement, such as dancing (Hahn et al., 2013), as well as in recovery processes with respect to running in neuromuscular performance after a marathon (Martínez-Navarro et al., 2021).

Regarding the field of quality of life and rehabilitation, it has been observed how, in patients with multiple sclerosis, the prescribed exercise on an elliptical machine improved the ranges of fatigue and quality of life (Huisinga et al., 2011). In this sense, an 8-week elliptical training program also improved motor, cognitive, and neurobehavioral function in adult subjects with chronic traumatic injury (Damiano et al., 2016). Likewise, in patients with cerebrovascular accidents, training on the elliptical for 8 weeks did not improve gait speed, but it obtained beneficial effects in other aspects such as resistance, balance and mobility of the same (Jackson et al., 2010).

Regarding the thermographic analysis, skin temperature has been related to muscle activation in incremental cycling tests in the lower limbs (Priego Quesada et al., 2015). Previous studies have verified how physical condition is related to thermoregulation and the changes produced in skin temperature and neuromuscular activation (Abate et al., 2013). In addition, to compare and evaluate different types of strength training and the effects produced before, during and after exercise, thermography has been used as a method of analysis (De Andrade Fernandes et al., 2014; Neves et al., 2015; De Almeida Barros et al., 2020).

On other machines, such as the exercise bike, there is a greater number of investigations in the comparative aspect between equipment (Sozen, 2010; Bouillon et al., 2016; Gillinov et al., 2017; Smith et al., 2019; Mady et al., 2019), both in the field of rehabilitation and performance (Sinha et al., 2013; Miki et al., 2014; Madsen et al., 2015; Ferraz et al., 2018), as well as in its thermographic analysis (Duc et al., 2015; Priego Quesada et al., 2015).

The DEC sports machine (Figure 1) corresponds to the Spanish patent with publication number ES2723981 and issue date 08/13/2021. Its design allows for a new cardiovascular and functional exercise in which all the joints and mobilizing muscles of the body receive resistance during both flexion and extension. As well as carrying out, if desired, proprioception and balance exercises together with cardiovascular exercise and, in addition, stretching and strength exercises with the weight of one's own body.

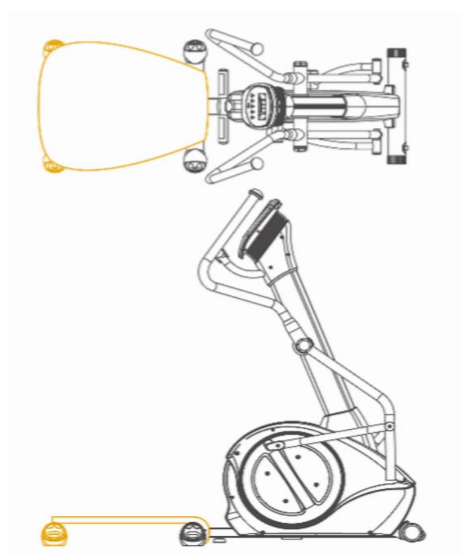

Figure 1. DEC Sports Machine.

The upper part of the DEC machine is designed for guided training of the upper body. It consists of two mobile handlebars that are operated by hand and that offer adjustable resistance to the forward and backward movement of the arms. Its two-way rowing system (2WR®) enables the athlete to perform the push and pull or push and rower exercise with both arms in parallel describing the same trajectory in unison, overcoming the same resistance in both directions without stopping during the exercise, even at high speeds. This exercise being named by the patent holder as *Main Position* (Figure 2). Being able to combine this exercise of the upper body with other exercises for the legs if you wish.

The lower part is designed for free and voluntary training of the lower body. It consists of a platform or step that allows you to perform from a slight leg flexion to deeper flexions or different choreographies. In this way, the athlete can perform the exercise called by the patentee as *Deconstruct* (Figure 3). Exercise in which the athlete continuously flexes and extends all the joints of the body, thus overcoming with the upper body the resistance offered by the handlebars and with the lower body the resistance offered by the mass or weight of their own body. Without both resistors overlapping each other.

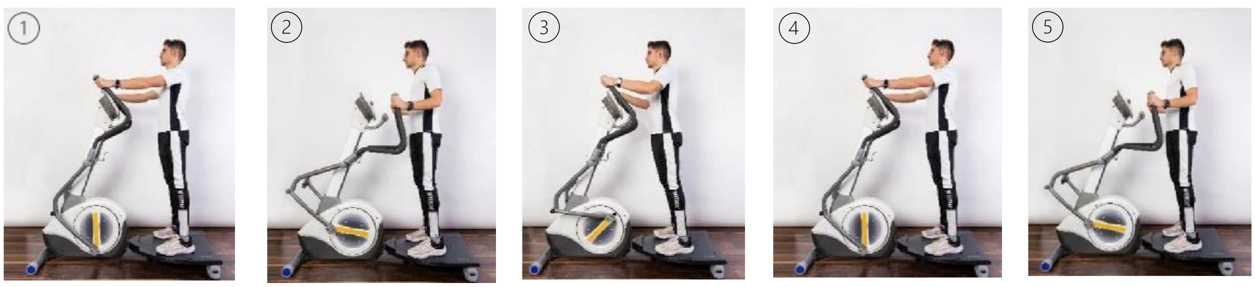

Figure 2. DEC Sports Machine. In main position (pull and push).

Using the machine in the main position results in muscle activation of the following parts of the body:

Pull Phase: Hands and forearms, arm biceps, posterior shoulder, back and core muscles (abdomen, lower back, glutes) as stabilizers.

Push Phase: Hands and forearms, triceps of the arm, front shoulder, pectoral and core muscles (abdomen, lower back, glutes) as stabilizers.

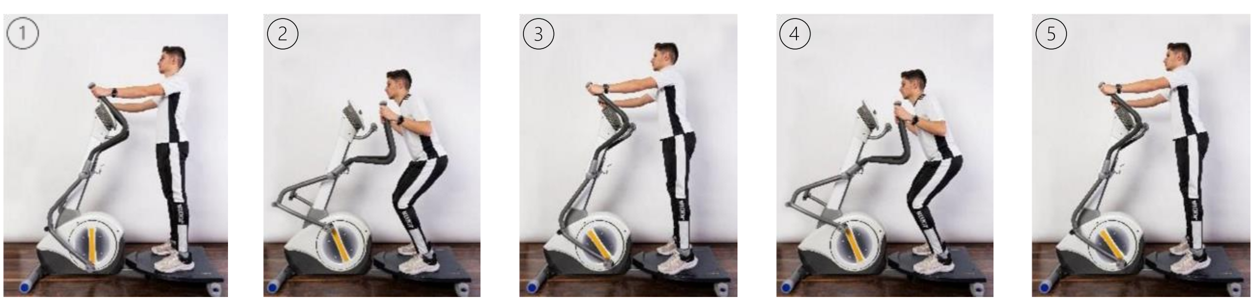

Figure 3. DEC Sports Machine. In the Deconstruct exercise (*pull and push* with light squat).

And the use in the Deconstruct exercise results in the muscle activation of the following parts of the body:

Pull and Down phase: Hands and forearms, arm biceps, posterior shoulder, back, abdomen, glutes, quadriceps, hamstrings and calves.

Push and Up phase: Hands and forearms, arm triceps, front shoulder, pectoral, lower back, abdomen, gluteals, quadriceps, hamstrings and calves.

Differentiating this comparison between low and high intensity training is due to the fact that the populations for which these two types of training are intended have different needs. In a non-limiting way, low-intensity training is considered that intended for populations such as the elderly, sports initiation, children, rehabilitation, physical reconditioning or health in the workplace. And as high intensity training that intended for professional or amateur sports performance, gyms, high intensity or interval training centres, group classes and professions such as firefighters, performing arts or rescue forces.

The Deconstruct Elliptical machine is a new and different cardiovascular training machine from the already known treadmill, stationary bike, rowing machine or elliptical, and there are no previous studies. For this reason, its investigation is necessary to determine its suitability for its use in its different applications. In this article, using thermographic technology, we analyse the differences in muscle functionality between the Domyos 680 (BED) elliptical bike (www.decathlon.es) and the new Deconstruct Elliptical 331-EF (DEC) machine from the Deconfree brand (www.deconfree.com). In addition, the physiological response was analysed by measuring the effects on heart rate (HR) and energy expenditure (EE) in various stress tests at different intensities, comparing the response obtained on both machines.

MATERIAL AND METHOD

Participants

A total of 8 physically active and healthy male subjects (mean ± Standard Deviation; age: 28.45 ± 1.75 years; height: 1.84 ± 0.07 m; body weight 76.42 ± 8.62 kg; Body Mass Index: 25.5 ± 2.6) participated in the present study. They carried out the intervention voluntarily. They all belong to the same group.

Process

Unlike the Elliptical machine, in which the intensity of the exercise can only be regulated through the adjustment of the resistance element (brake on the flywheel), in the Deconstruct Elliptical machine the intensity of the exercise in addition to this same adjustment, it can be modified by incorporating different lower body exercises while continuing to exercise the upper body. For the purposes of the study, to compare the two machines at low and high intensity, two exercise protocols described in Table 1 were carried out.

Below is a schematic description of the exercises carried out in the DEC for the LIP and for the HIP:

Exercise carried out in the LIP

For the LIP, the Deconstruct exercise was selected because it involves a continuous activation of the arms and legs muscles, as it happens in an elliptical machine. It consists of the forward/backward movement of the arms in parallel, overcoming the resistance offered in both directions by the handlebars (*push and pull),* as well as the up/down movement of the legs in parallel performing a light squat (LS). Carrying out the flexion/extension of both segments in unison (Figure 3).

Table 1. Exercise protocol: low intensity (LIP) and high intensity (HIP).

	Low Intensity Protocol (LIP)	High Intensity Protocol (HIP)
BED	Intensity: Gradual resistance adjustment Type of exercise: Known motion on an elliptical bike	Intensity: Gradual resistance adjustment Type of exercise: Known motion on an elliptical bike
DEC	Intensity: Gradual resistance adjustment Type of Exercise: Deconstruct Exercise (DE): Push and pull (PP) with Light squat (LS)	Intensity: Gradual resistance adjustment Types of exercises: DE with medium squat (MS) DE with stride squat (SS) DE with deep squat (DS) DE with maximum deep jumps (MDJ)

Exercises carried out in the HIP

For the HIP, among several high intensity positions, the following were selected:

- Deconstruct exercise with medium squat -MS- (Figure 4).
- Deconstruct exercise with stride squat -SS- (Figure 5).
- Deconstruct exercise with deep squat -DS- (Figure 6).
- Deconstruct exercise with maximum deep jumps -MDJ- (Figure 7).

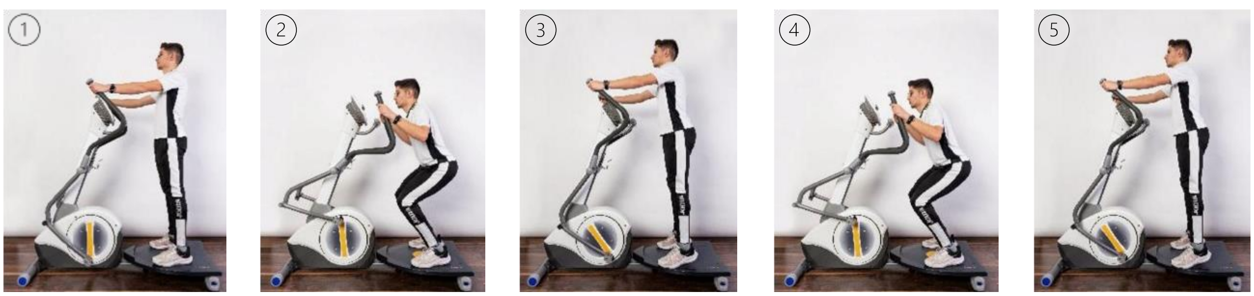

Figure 4. Deconstruct exercise with medium squat (MS).

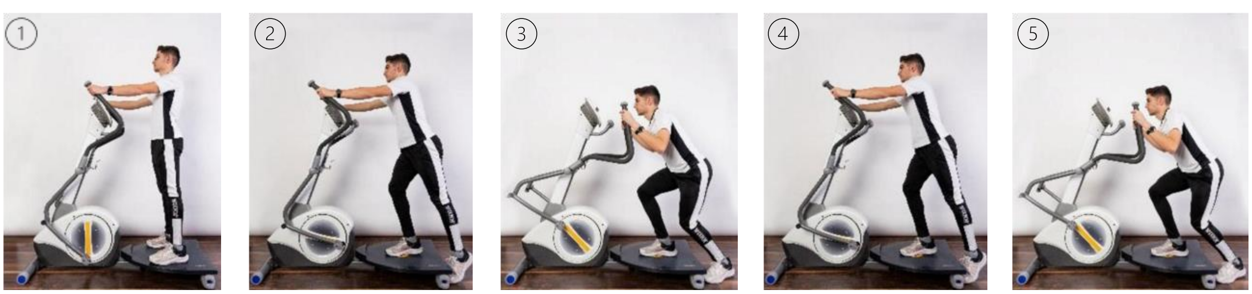

Figure 5. Deconstruct exercise with stride squat (SS).

Figure 6. Deconstruct exercise with deep squat (DS).

Figure 7. Deconstruct exercise with maximum deep jumps (MDJ).

The DEC machine allows other types of exercises or training positions in addition to those studied here but which have not been described as they are not the object of the study.

For more information the reader can refer to their website (www.deconfree.com).

The development of the research was carried out at the University of Alicante in 2020 for three days. On the first and second day, the measurements were taken using the Domyos 680 elliptical bike (BED) and the Deconstruct Elliptical 331-EF (DEC) machine, the participants exercising on both machines according to the low intensity protocol (LIP). The third day of the investigation focused on a comparison between equipment applying the high intensity protocol (HIP). The tests were carried out under controlled environmental conditions (indoors). During a previous week, the participants were informed about the development of the research and the duration of the tests.

Tests and trials carried out

The thermographic analysis was carried out in the (LIP) carrying out a stress test at different intensities in the BED and DEC machines. For this, thermal images of the trunk and legs were taken in their anterior and posterior views. The different shots were taken before starting the test and once at the end of each of the intensities. On the BED elliptical, an initial baseline shot and 6 subsequent shots were made at 6 different and incremental exercise intensities. In the case of the DEC, it was a basal shot and, after that, 5 shot at 5 incremental intensities. In all cases, an acclimatization period was followed and the same FLIR T530 camera with ThermoHuman software was used for image analysis.

The HR and the EE were carried out in the LIP and HIP. Energy expenditure (EE) was calculated during the exercises using the Harris and Benedict Equation (1919).

Measures

Thermographic analysis in LIP

The software used for the research showed an analysis of the different regions of interest of the body. In figures 8 and 9, you can see the different colours that represent the significant variations in temperature in the different areas analysed. In the present study, mainly the thermal asymmetries (comparison between bilateral regions), the coefficient of variation (hyper or hypothermic variations depending on the standard deviation) and mean temperature values per region are collected.

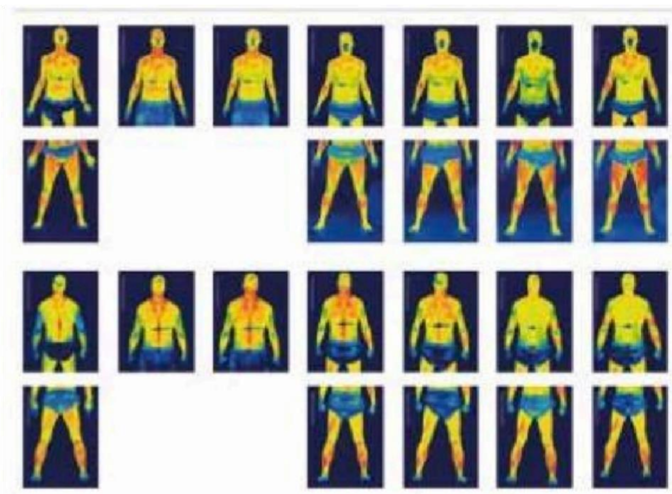

Figure 8. Thermograms of the test carried out with the BED machine.

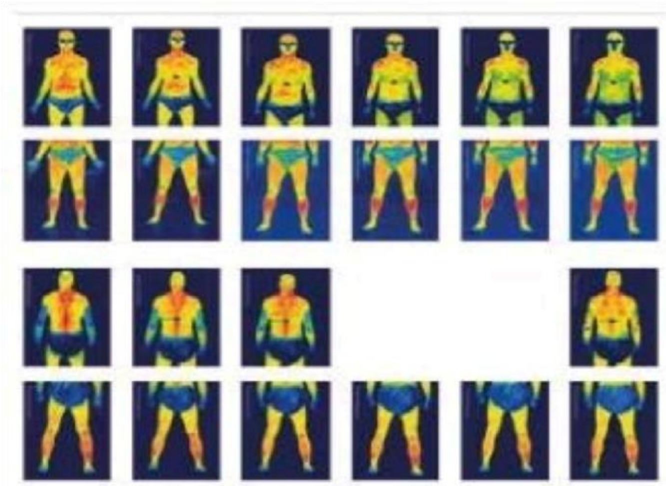

Figure 9. Thermograms of the test carried out with the DEC machine.

Stress test in LIP

A stress test was performed at different intensities on the different machines. HR was collected using Polar H9 heart rate straps. In addition, perceived exertion (RPE) was added at different intensities using the Borg scale as a reference (Borg, 1970). Finally, the caloric expenditure measured in METs and calories/minute was analysed.

Comparative analysis in the HIP
For the high intensity proposal, the protocol described in the Procedure section was selected. RPE and HR were used as a measure of perceived exertion and a comparison of the HR obtained on the two machines was made. Thermometric measurements were not taken for this comparison.

Statistical analysis
The one-way ANOVA test was used to analyse the thermography values obtained from the muscles analysed during the exercises using the SPSS 25.0 program (SPSS Inc., Chicago, IL, USA). In addition, the differences between the groups were verified through the Scheffe test, a Post hoc test. The significance level used in this study was $p < .05$.

RESULTS

Average temperature asymmetries by region
In the following metric (figures 10 and 11) all the zones are compared bilaterally, showing those that are hotter from 0.3ºC. In this case, it can be seen how the BED machine generated a prominent asymmetry in the right arm, while in the DEC machine it was less prominent, being more localized in the forearm. Due to the segmentation problem we avoided the alarms in the hamstrings and adductors. On the other hand, we highlight that the DEC machine increased the asymmetries in the heel and inner calf of the right leg.

Figure 10. BED machine asymmetries.

Figure 11. DEC machine asymmetries.

Neutralized asymmetries
In the following avatars (figures 12 and 13) individualized asymmetry is shown for each region. The number of alarms is reduced and the cut-off points are individualized as long as there is no pain and/or injury. In this case, the measure does not generate very solid results over time in the case of the BED machine and the DEC machine.

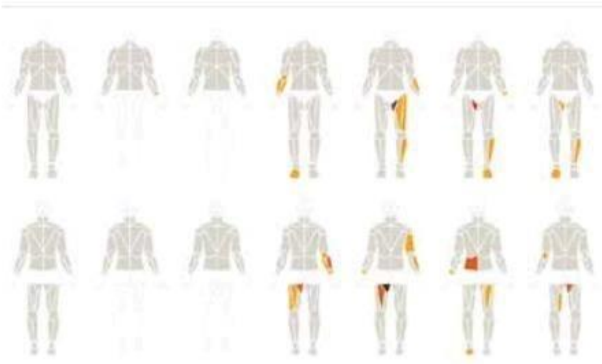

Figure 12. BED neutralized asymmetries.

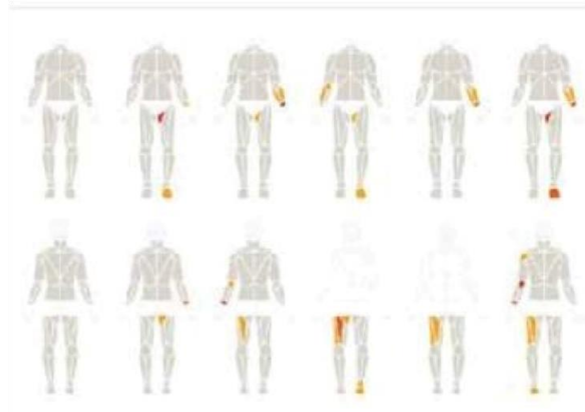

Figure 13. DEC neutralized asymmetries.

Coefficient of variation

In the following complementary metric (figures 14 and 15), hyper and hypothermic trends are observed without dependence on the asymmetry or the absolute values of temperature. When analysing the thermal trends, it is observed that, in the BED machine, the gradual heating of the forearms and triceps stands out. However, in the DEC machine, higher coefficient values are generated in those regions, including the shoulders and anterior forearm.

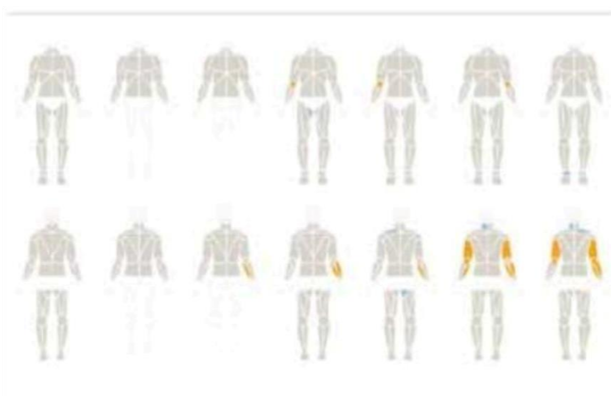

Figure 14. Smoothed coefficient of variation(BED machine).

Figure 15. Smoothed coefficient of variation (DEC machine).

Total thermographic analysis

In the following figures 16 and 17, a total thermographic analysis can be observed in both machines in relation to the average temperature obtained from the anterior shoulder, biceps brachial, dorsal and pectoral regions. If we analyse the results, we observe that there are two easily recognizable trends: On the one hand, in the case of the BED machine, the temperatures of the regions mentioned above have a symmetrical and quite similar behaviour throughout the test, with a decrease in the last test. On the contrary, the DEC machine also demonstrates a fairly symmetrical behaviour with an increasing trend in the shoulder and biceps, observing maintenance with a slight decrease in the case of the pectoral muscle.

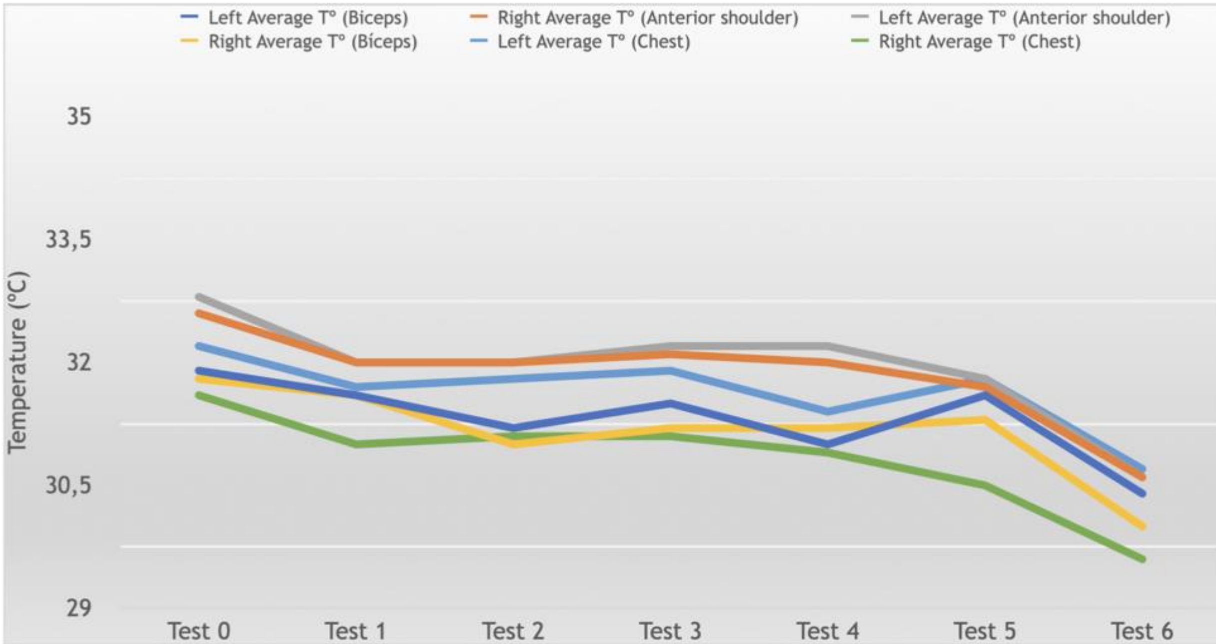

Figure 16. Total thermographic analysis (BED machine).

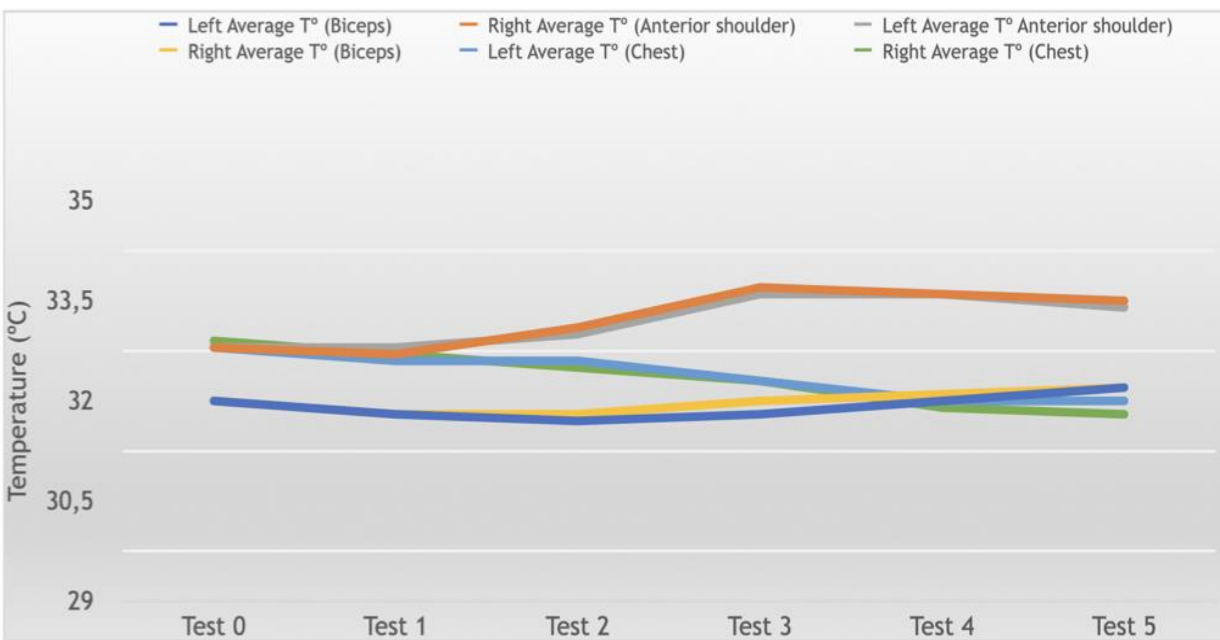

Figure 17. Total thermographic analysis (DEC machine).

Analysis of the HR in LIP

Table 2 shows the HR values (absolute and relative) on both machines, as well as the different degrees of intensity using a scale of perception of effort (Borg, 1970). The BED machine presents higher work intensities than the DEC machine. However, in the present study no significant differences were found in terms of the HR reached in both machines ($p < .05$).

Table 2. Heart rate (HR) analysis in LIP. Mean and standard deviation.

BED machine			DEC machine		
Intensity	HR (bpm)	% HR	Intensity	HR (bpm)	% HR
2	72	42	3	88	50
4	104	52	6	98	56
6	115	65	9	104	59
8	123	70	12	109	62
10	128	73	15	112	64
12	137	78			
Average ± SD	113 ± 23.1	64.5 ± 13.7	Average ± SD	102 ± 9.5	58.2 ± 5.5

As can be seen, the average HR is lower in the DEC machine, reaching lower exercise intensities, but without significant differences ($p < .05$).

Analysis of the EE in LIP

Table 3 shows the EE data (METs and calories/minute) in both machines. The DEC machine presents a lower EE compared to the BED machine. However, at a statistical level no significant difference is found in the established protocols ($p < .05$).

Table 3. Analysis of caloric expenditure obtained in both machines in LIP.

BED machine			DEC machine		
Intensity	MET	Cal/min	Intensity	MET	Cal/min
2	2.3	3.14	3	2.9	4
4	3.4	4.64	6	3.2	4.4
6	3.7	5.1	9	3.4	4.6
8	4	5.5	12	3.5	4.8
10	4.1	5.6	15	3.6	4.9
12	4.5	6.2			
Average ± SD	3.7 ± 0.7	5.03 ± 1.1	Average ± SD	3.3 ± 0.3	4.5 ± 0.4

HR analysis in HIP

Table 4 shows the HR data (absolute value and percentage) obtained on both machines according to the protocol described (Table 1). It can be observed how the DEC machine shows higher values and intensities than the BED machine, obtaining significant differences between both tests ($p < .05$).

Table 4. Comparison of HR in HIP.

BED machine			DEC machine		
Intensity	HR (bpm)	% HR	Intensity	HR (bpm)	% HR
6	117	67	6 MS*	134	76
8	126	72	9 SS*	141	80
10	139	79	12 DS*	158	90
12	145	82	15 MDJ*	174	99
Average ± SD	131.7 ± 12.6	75 ± 6.7	Average ± SD	151.7 ± 17.9	86.2 ± 10.3

*Note. *MS: Medium squat; SS: Stride squat; DS: Deep squat; MDJ: Maximum deep jumps.*

As we can see, the percentage of maximum HR obtained on the DEC machine exceeds 86% while on the BED machine 75% of maximum HR is obtained.

Therefore, the exercise intensity is higher in the DEC machine in HIP.

EE analysis in HIP

Table 5 shows the EE data (METs and calories/minute) in both machines. The DEC machine presents a higher EE compared to the BED machine, whit significant differences between both protocols ($p < .05$).

Table 5. Analysis of caloric expenditure obtained in both machines in HIP.

BED machine			**DEC machine**		
Intensity	MET	Cal/min	Intensity	MET	Cal/min
6	7.4	9.9	6 MS*	9.4	12.6
8	8.4	11.4	9 SS*	10.4	14.1
10	10.1	13.6	12 DS*	12.6	17
12	10.6	14.3	15 MDJ*	14.7	19.8
Average ± SD	9.1 ± 1.5	12.3 ± 2	Average ± SD	11.8 ± 2.7	15.9 ± 3.2

*Note. *MS: Medium squat; SS: Stride squat; DS: Deep squat; MDJ: Maximum deep jumps.*

DISCUSSION

The objective of this study was to establish the differences in muscle functionality and physiological response during exercise between the BED machine and the DEC machine for low and high intensity training, as well as to determine its suitability for different audiences.

In the present investigation, in the low intensity test, it was observed that there is a greater hyperthermic tendency in the upper extremities, being more relevant in the shoulder and biceps in the DEC machine and higher in the lower limbs in the BED machine. Thermographic measurements were not made for high intensities, but it would be expected that they would be higher in DEC due to the higher HR value obtained in this modality (Marins et al., 2015). On the other hand, during the established tests, two trends in the temperatures of some regions of the upper body (anterior shoulder, biceps, dorsal and pectoral) are differentiated. On the one hand, the BED machine, in terms of temperature analysis, behaves in a regular and symmetrical but decreasing manner. However, the DEC machine follows a symmetric and also incremental behaviour in temperature. Regarding the analysis of parameters such as HR or EE obtained in tests performed at low intensity, our study did not find significant differences between both machines ($p < .05$). However, when comparing HR and EE in high intensity training (HIP) on the DEC machine, significant differences were found between the two machines, being higher on the DEC machine ($p < .05$).

The importance of aerobic exercise has been demonstrated in numerous studies in the improvements produced at the cardiovascular level (Niebauer & Cooke, 1996; Miele & Headley, 2017; Nystoriak & Bhatnagar, 2018) and its importance in the EE (Strasser & Schobersberger, 2011; Drenowatz et al. al., 2015; Gastin et al., 2018; Ostendorf et al., 2019; Berge et al., 2021). That is why sports sciences are in constant evolution looking for methods and scientific research to improve sports performance and rehabilitation (Sozen, 2010). In this sense, there are many works and investigations that compare different exercise machines and methodologies, providing information on physiological parameters (Rebelo et al., 2015; Klein et al., 2016; Lesmawanto et al., 2019; Filipovic et al., 2021).

Machines such as the cycle ergometer or the treadmill have traditionally been the most common for determining maximal oxygen consumption tests (Dalleck et al., 2004). They have been studied to observe their relationship with fat oxidation and their relationship with benefits at the cardiometabolic level (Filipovic et al., 2021), showing, for example, a higher proportion of oxidation on a treadmill compared to cycling (Chenevière et al., 2010). In this sense, some tests carried out on the elliptical and treadmill have not found significant differences in the values reached for maximum oxygen consumption in trained men and women (Dalleck, 2004). On the other hand, in previous investigations in which other machines such as the bicycle are analysed, they have determined differences in terms of fat oxidation with respect to other modalities and their active muscle mass (Achten et al., 2003). In relation to the elliptical and the treadmill, the various effects produced with respect to body composition, HR and maximum oxygen consumption have been observed, obtaining similar improvements (Mercer et al., 2001; Donne & Egana, 2004). Other works carried out with the elliptical did not find significant differences in terms of the improvement of the maximum oxygen consumption in trained runners beyond the initial 4 weeks, which led to a significant improvement like any aerobic exercise when starting a program (Joubert et al., 2011). In our study, when comparing the different machines in low intensity training, no significant differences were found between the BED machine and the DEC machine ($p < .05$). However, in high-intensity training, higher data were found on the machine DEC ($p < .05$).

Regarding thermographic analysis, some studies suggest using this technology to observe physiological responses to sports training and physical exercise (Neves et al., 2015; Neves et al., 2015). In this sense, the relationship between skin temperature and the neuromuscular response in lower limbs has been seen in incremental cycling tests (Priego Quesada et al., 2015; Duc et al., 2015). Depending on the intensity and type of exercise performed, it has been shown how the skin temperature over active muscles increases or decreases (Neves et al., 2015). On the other hand, thermography has been used in other fields of knowledge such as health (Neves et al., 2016; de Jesus Guirro et al., 2017; Neves et al., 2017). However, in the field of comparison between different machines in general, and in particular the elliptical, there is no extensive literature on the matter. Therefore, more research is needed in this aspect.

If we focus on the biomechanical analysis, some studies have compared the influence on different joints between different machines (Damiano et al., 2011; Rogatzki et al., 2012), considering the elliptical or the bicycle as good equipment to take into account for the rehabilitation of athletes and the recreational field (Johnston, 2007; Lu et al., 2007). It has been seen how the activation is greater in the upper limbs in the elliptical with respect to other machines such as the treadmill or the bicycle (Sozen, 2010). In addition, in another work it was observed how the involvement of the quadriceps and hamstrings was greater in the elliptical than in the bicycle or walking by means of electromyography (Prosser et al., 2011). On the other hand, studies have been proposed that support the need to incorporate training on a bicycle, treadmill or elliptical for the improvement and rehabilitation of different pathologies (Sweitzer et al., 2002; Harris et al., 2003; Laoutaris et al. , 2013; Fex et al., 2015; Yuing Farías et al., 2019). Therefore, we can consider these equipment as valid instruments both for improving sports performance, rehabilitation and improving quality of life according to the literature analysed.

In this sense, the DEC machine is considered interesting equipment in populations that need low-intensity training. And if we carry out the high intensity protocol in DEC, the intensity increases with respect to HR and EE, which shows that its use could also be extended to other areas such as sports performance.

Finally, it should be considered that the dorsal muscle is interrupted in the thermographic analysis since two images were not processed correctly. It would be expected, however, that since there is a greater hyperthermic tendency in the upper extremities, being more relevant in the shoulder and biceps, and taking into account the motor link between the biceps and the dorsal muscle, said dorsal muscle would have had a similarly greater hyperthermic tendency in DEC (Gutiérrez-Vargas et al., 2017). In contrast, not only the lats but also all the upper body muscles measured in the thermography show a gradual deactivation in the BED that is very clearly observable in Figure 16. This demonstrates what was observed by Batté et al. (2003) about the need to be aware during the exercise of activating the upper body on the Elliptical, which is not plausible as the data from this study show. In the Deconstruct Elliptical, due to its design, the upper body is working continuously without the need for the user to be aware during the exercise. The fact that, unlike the BED, the DEC offers multiple positions for the lower body, opens up a new field of study on the DEC. The authors suggest that more comparative studies with the Elliptical machine and other widely used and studied cardiovascular machines such as the treadmill, stationary bike or rowing machine, are necessary to help better understand the Deconstruct Elliptical machine.

CONCLUSIONS

The Elliptical machine is endorsed both by its widespread use and by the numerous studies carried out that show its suitability for different types of training. But the results obtained in this research suggest that the Deconstruct Elliptical is a cardiovascular machine that improves muscle functionality and the physiological response of the Elliptical machine.

In the present comparative study, the thermographic analysis shows that muscular functionality in the DEC machine is progressive and continuous. On the contrary, in the BED machine it is descending. This is a quality that would highlight better muscle functionality on the DEC machine over the BED machine and would make it more appropriate for low intensity training or conditioning and rehabilitation.

On the other hand, the DEC machine in its high intensity protocol exceeds the HR and EE value obtained in the BED machine with a continuous, gradual and ascending degree of muscle activation that does not occur in BED. Which places the DEC machine in a more favourable position with respect to the BED machine for populations that need high intensity training such as sports performance or in gyms, being able to extend its use to this area.

This is the first study done on the Deconstruct Elliptical as it is a novel cardiovascular machine. Due to the numerous exercises that are possible and that could not be collected in this study, it is suggested that more research is necessary to measure their effects. Also due to its importance for the health of the back, it would be of great interest to measure the activation of the lats in the DEC and verify that it actually increases over time, as occurs with the shoulders and biceps.

AUTHOR CONTRIBUTIONS

C.E.A. manuscript writing, collected the data, preparation and research design; M.T.S. manuscript writing and statistic analysis; M.J.G.G. critically reviewed the work and result interpretation; C.S.L. research design and critically reviewed the work.

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No potential conflict of interest was reported by the authors.

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SCIENTIFIC JOURNAL OF SPORT AND PERFORMANCE

ORIGINAL ARTICLE

Age-related differences in the specific test on taekwondo players

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ABSTRACT

In studies on agility in sports, changes in agility with age have been frequently investigated. It is not precisely known how the taekwondo-specific agility test will changes according to age. This study aimed to identify and compare the specific taekwondo agility abilities of elite taekwondo players in different age groups. Twenty-seven taekwondo players (14 males-13 females) between the ages of 11-15 participated in the study. The players were divided into 2 age groups: 11-12 and 13-15 years old. Each participant completed three tests: The taekwondo-specific agility test (TSAT), Zigzag agility test (ZT) and standing long jump test (SLJ). The anthropometric characteristics were also evaluated. Then, TSAT, ZT, and SLJ tests were performed on the other day. The results indicated that there were significant differences in TSAT, ZT, and SLJ among the age groups. In addition, significant differences in BMI, height, and weight were observed between groups ($p < .05$). The athletes in the 13-15 age group performed considerably better in the TSAT, ZT, and SLJ tests. The results also indicate that taekwondo players aged 11-12 years can improve their performance more with ZT and TSAT exercises than SLJ exercises.
Keywords: Performance analysis of sport, Physical conditioning, Change of direction, Specific testing, Physical fitness, Growth, Development, Children.

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INTRODUCTION

Taekwondo is a combat sport that has been in the Olympics since the year 2000. Taekwondo moves include kicks and punches to the opponent's torso and head on a 12mx12m square area. In taekwondo tournaments, players are categorized according to their weight and age.

Taekwondo actions involve high-intensity bouts of short duration (1-3 seconds), performed in a limited area with rapid changes of direction (Hausen, 2017; Santos, 2011). The matches consisted of three rounds (2-minutes each with one minute of rest). Campos et al. (2012) demonstrated that Taekwondo is predominantly aerobic (66%). However, high-intensity movements (i.e., a moment of attack or defence) were maintained by the ATP-PCr system (30%), with a low contribution from the glycolytic system (4%). Agility has special importance in taekwondo because of the large number of atypical situations that demand multiple rapid changes of direction in the relatively small space of the court. The physiological profile of taekwondo athletes, as well as their acute and chronic adaptations to taekwondo, have been extensively studied recently (Tasiopoulos, 2015; Nikolaidis and Tasiopoulos, 2015; Tasiopoulos, 2014); however, the relationship between kicking performance and agility in taekwondo athletes has not been clearly established. In addition, most studies measured agility, but not taekwondo-specific agility (Singh, 2015; Singh and Sathe, 2017). In addition, studies in the literature are limited to specific agility related to taekwondo. The Illinois Agility Test (IAT), zigzag agility test, and agility T- test are commonly used in studies to assess agility. According to Hachana (2013), these tests are the most effective for measuring agility. Motoric characteristics, such as agility, strength, and speed of change of direction, are crucial in Taekwondo to achieve high performance during the game. These characteristics change with age during childhood and adolescence (Malina, 2004). Studies have stated that agility performance time decreases until early middle age. This decrease in agility was divided into three phases. The first group (7–10 years old) had a 27.1% decrease in agility time. In the second group (10–14 years old), the decrease was 26.5%, and in the third group (14–18 years of age), there was a 16.5% decrease (Henrieta and Hornikova, 2019). Agility performance mostly improves between 5 and 8 years of age, and then continually improves up to 18 years (Malina, 2014). Another study showed that agility time was significantly different between 13 and 14 years old but not between 12 and 13 years old (Horicka, 2018). In addition to the importance of agility in taekwondo, explosive strength and specific taekwondo agility are important. Taekwondo-specific agility is required to quickly perform all-out technical-tactical movements in multidirectional planes by maintaining dynamic balance, speed, and precision, maintaining and controlling correct body positions while quickly changing direction through a series of movements. Taekwondo exercises and repetitions of specific taekwondo movements improve these features. Also, valid tests involving these techniques are used to measure taekwondo-specific agility (Chaabene, 2018; Tasiopoulos, 2015).

Taekwondo includes many specific kicks, punches, and self-defence performances. During the game, it is necessary to create a specific kick or punch technique for some body parts to earn points. Moreover, knowing taekwondo requirements according to age will benefit trainers. Therefore, taekwondo training requires a specific and different approach to designing physical preparation practice. The aim of this study was to identify the specific taekwondo agility abilities and compare the different agility abilities of different age groups of elite male and female taekwondo players.

MATERIALS AND METHODS

Participants

Twenty-seven (14 males-13 females) elite-level junior taekwondo athletes (mean ± SD: age:12.81 ± 1.6 years; height:158.3 ± 11.1 cm; Weight:49.2 ± 9.2; body mass index:19.48 ± 2.13) participated in the study. Athletes consisted in national and international taekwondo events of different weight categories. Athletes have at least 4 years of taekwondo training and competition experience. None of them was involved in any weight loss procedures during the experimental period, which was conducted during the in-season period of the competitive year. All the athletes completed the study. Groups are divided into 2 groups:11-12 years old (Mean ± SD: age:11.9 ± 0.7 years; Height:149.1 ± 8.07 cm; Weight:40.1 ± 5.94 kg; body mass index:17.98 ± 1.83; Experience; 4.91 ± 1.04 years), and 13-15 years old (Mean ± SD: Age: 14 ± 0.8 years; Height: 164.5 ± 8.32 cm; Weight: 55.44 ± 4.70 kg; Body mass index: 20.51 ± 1.68; Experience: 5.75 ± 1.06 years). Athletes were verbally informed about research protocols prior to participation in the study. A comprehensive verbal description of the nature and purpose of the study, as well as of the experimental risks, was provided to the children, adolescents, their parents/guardians, and teachers. This information was also sent to parents and guardians by regular mail, and written informed consent was obtained from parents and children before participation. The study was conducted according to the Declaration of Helsinki and was approved by the Institutional Review Committee for the Ethical Use of Human Subjects at Dokuz Eylül University, Turkey(The approval number: 2021/26-37- 22.09.2021).

Procedures

Each participant completed three tests: the TSAT, zigzag agility test, and Standing Long Jump test. The time in seconds and hundreds of seconds were determined using an electronic timing system (Microgate, Bolzano-Bozen, Italy).

Anthropometric characteristics of the athletes were measured at the beginning of the testing session. The TSAT, ZT, and SLJ tests were performed on the second day. Before the tests, the athletes were asked to wear clothes and shoes that did not restrict their movements. Athletes were informed that they should not perform any intensive activities 48 hours before the measurements. After anthropometric variables were measured and recorded for each athlete, a standard warm-up was performed by the researcher. Tests were conducted indoors on the taekwondo tatami from 16:00–18:00 in a randomized, counterbalanced order, with breaks between tests ranging from 5 to 10 min. Tests were preceded by a 10-minute warm-up, including 5 minutes of running with the remaining time dedicated to static and ballistic stretching, as well as specific submaximal exercises such as kicking, squatting, and jumping. Subsequently, participants were allowed to perform two submaximal trials for each test. First, the zigzag agility and Standing Long Jump tests were performed. After this measurement, the athletes performed a Taekwondo-specific agility test in the tatami field. For reliability purposes, the test was repeated twice for each participant and the best value was recorded. Each test was performed at the same place and time of the day (4-6 pm), and the tests were completed in September. All the instruments were calibrated to ensure acceptable accuracy.

Anthropometric measurements

Height was measured with a stadiometer (Seca 220, Birmingham, United Kingdom) to the nearest 0.1 cm, and body mass was recorded using a portable scale (Tanita BF683W, Munich, Germany) to the nearest 0.1 kg. Body mass index (BMI) was derived from the results of height and body mass, dividing body mass by height squared. During the measurements, participants were barefoot and dressed in shorts only.

Taekwondo-specific agility test (TSAT)

From a guard position with both feet behind the start/finish line, the performer had to: (a) move forward in guard position without crossing feet as quick as possible to the centre point, (b) turn toward partner 1 by adopting a lateral shift and perform a roundhouse kick with the left leg (i.e., leading-roundhouse kick; dollyo-chagi); (c) move toward partner 2 and perform a roundhouse kick with the right leg (i.e., leading-roundhouse kick; dollyo-chagi); (d) return to the centre; (e) move forward in the guard position and perform a double-roundhouse kick (i.e., narae-chagi) toward partner 3, and (f) move backward to the start/finish line in a guard position (Figure 1). Sparring partners 1 and 2 holds a kick-target, whereas partner 3 holds two kick targets. Sparring partners were instructed to maintain the kick-target at the torso height of the tested athlete. If a participant failed to follow these instructions (e.g., crossed 1 foot in front of the other during the various displacements or failed to touch the kick-target powerfully when kicking), the trial was terminated and restarted after a 3-minute recovery period. The time needed to complete the test was used as a performance outcome and was assessed using an electronic timing system (Brower Timing Systems, Salt Lake City, UT, USA). Two trials were given to each athlete and the best one was recorded. (Chaabene, 2018).

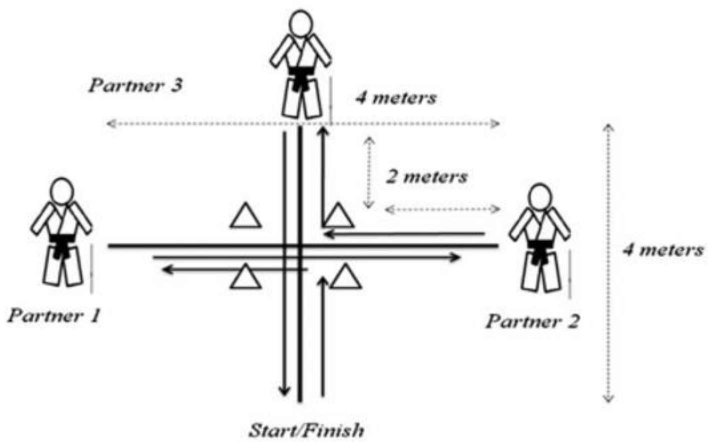

Figure 1. Taekwondo-specific agility test.

Zigzag Agility Test (ZT)

The participants ran one lap as fast as they could around a 3 m- 4.85 m zigzag path marked with tape on the floor and cones in every corner. The test was repeated twice, and the best score was retained(Ortiz, 2005). (ICC: 0.92)

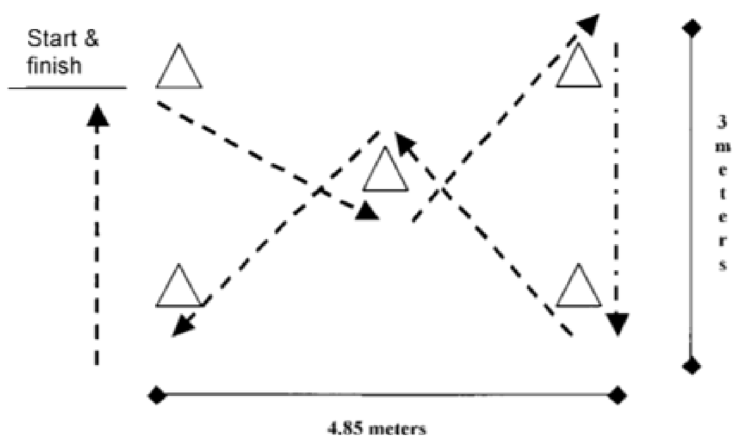

Figure 2. Zigzag Agility Test.

Standing Long Jump Test (SLJ)

The participants stood behind the starting line, with their feet together, pushed off vigorously, and jumped forward as far as possible. The distance is measured from the take-offline to the point where the back of the heel is nearest to the take-off line landing on the mat or non-slippery floor. The test was repeated twice, and the best score was retained (cm) (Castro, 2009).

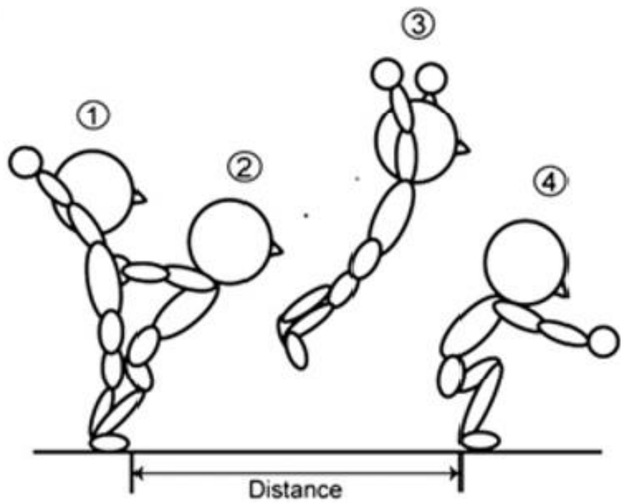

Figure 3. Standing Long Jump Test.

Statistical analyses

The collected data were statistically processed using SPSS statistical program for Windows (version 20.0; SPSS, Inc., Chicago, IL, USA). Elementary descriptive parameters (mean, SD, maximum, and minimum) were calculated. The normality assumption was checked using the Shapiro-Wilk test, and all variables showed a normal distribution. The T-test for independent samples was used to determine significant differences in TSAT, Zigzag agility test, and standing long jump between these groups. According to the descriptive characteristics of this study, the correlation between age and performance skill variables was checked using the elementary causal procedure (Pearson's correlation coefficient) for each group. The level of significance was set at $p \leq .05$.

RESULTS

Table 1. Characteristics of players.

	n	*Age*	*Height (cm)*	*Weight (kg)*	*BMI*	*Experience (years)*
11-12 yrs. of age	11	11.9 ± 0.7	149.1 ± 8.07	40.18 ± 5.94	17.98 ± 1.83	4.91 ± 1.04
13-15 yrs. of age	16	14 ± 0.8	164.5 ± 8.32	55.44 ± 4.70	20.51 ± 1.68	5.75 ± 1.06

Athletes were divided into two distinct age groups as 11-12 and 13-15 years old ahead of the study. Table 1 shows the physical qualities and body compositions of the two groups.

Table 2 illustrates the TSAT, ZT, and SLJ values of 11-12- and 13–15-year-old taekwondo players. Additionally, Table 2 shows the height, weight, and BMI of the athletes and the outcomes of the comparison between these two groups. There were significant differences in TSAT, ZT, and SLJ among the age groups. There were significant differences in BMI, height and weight between groups. ($p < .05$).

Table 2. Means, SD, maximum and minimum of all variables for the comparison between these 2 groups (results of t-test).

	11-12 yrs. of age			***13-15 yrs. of age***				
	Mean ± SD	Min	Max	Mean ± SD	Min	Max	t	*p*
TSAT (sn)	5.85 ± 0.3	5.38	6.28	5.37 ± 0.35	4.80	6.00	3.08	**.00****
Zigzag test(sn)	7.31 ± 0.4	6.76	8.13	6.82 ± 0.39	6.18	7.47	3.68	**.00****
Standing long jump (cm)	158.09 ± 19.38	137	201	175.13 ± 20.29	138	207	-2.18	**.03***
Height (cm)	149.1 ± 8.07	135	159	164.5 ± 8.32	152	181	-4.77	**.00****
Weight (kg)	40.18 ± 5.94	26	48	55.44 ± 4.70	49	65	-7.43	**.00****
BMI	17.98 ± 1.83	14.27	21.05	20.51 ± 1.68	17.24	22.96	-3.69	**.00****

*Note. **Sig. (p < .001), *Sig. (p < .05). t = T-statistic value.*

Table 3. Correlation coefficients between all variables in the 11-12-year-old group.

	TSAT	**Zigzag test**	**Standing long jump**
TSAT	1		
Zigzag test	.793**	1	
Standing long jump	-.605*	-.525	1

*Note. **. Correlation is significant at the .001 level (2-tailed). *. Correlation is significant at the .05 level (2-tailed).*

Table 3 shows the correlation between the variables in the group of 11–12-year-old players. The values demonstrate the relationship between the agility tests(zigzag test and TSAT) and SLJ. Although there was a positive correlation between ZT and TSAT, there was no correlation between ZT and SLJ. While the correlation between TSAT and SLJ was − -0.60, the correlation between TSAT and ZT was 0.79. This shows that the correlation between TSAT and ZT provides more accurate information for athletes aged 11-12. TSAT and ZT have a positive correlation; however, TSAT and Standing long jump have a negative correlation. According to post-hoc analysis of sample size [correlation TSAT-ZT = 0.79, correlation TSAT-SLJ = - 0.60, SLJ-ZT = -0.52 sample size= 11, type-1 error (α) = .05], values of this study was found.

Table 4. Correlation coefficients between all variables in the group 13-15-year-old players.

	TSAT	***Zigzag test***	***Standing long jump***
TSAT	1		
Zigzag test	.605*	1	
Standing long jump	-.538*	-.656**	1

*Note. **. Correlation is significant at the .001 level (2-tailed). *. Correlation is significant at the .05 level (2-tailed).*

The correlation between the parameters for players between the ages of 13-15 is shown in Table 4. For all tests of players aged 13-15, a correlation was discovered, as opposed to the correlation variables for children aged 11-12. The correlation between TSAT and ZT was 0.60, whereas the correlation between ZT and SLJ was − -.53. While TSAT and ZT have a negative correlation with SLJ, TSAT and ZT have a positive correlation with each other. According to post-hoc analysis of sample size [correlation TSAT-ZT = 0.60, correlation TSAT-SLJ = -0.53, SLJ-ZT = -0.65 sample size= 16, type-1 error (α) = .05], values of this study was found.

DISCUSSION

This study investigated and compared the TSAT and zigzag agility tests in taekwondo athletes between the ages of 11-12 and 13-15. Significant differences were observed between the two age groups. As expected, TSAT time, zigzag agility test time, and standing long jump results at 13–15-year-old were significantly better than those of the other group. Our data support and expand on previous findings that indicate the performance of agility tests on taekwondo players during early childhood. Agility performance increases continuously until pre-adolescence, and studies have shown that specific agility test performance also increases with age (Vescosi, 2011; Tasiopoulos, 2015). Agility is considered a fundamental prerequisite in taekwondo for the execution of kicking techniques (Bridge, 2014; Casolino, 2012; Pieter, 2000). Tasiopoulos et al. found a significant difference in agility performance and leg acceleration in taekwondo players under 12 years old (U12) and under 15 years old (U15). The agility performance and leg acceleration test data for the U15 age group were better than those for the U12 age group (Tasiopoulos, 2015). Furthermore, Nikolaidis et al. (2016) compared six different taekwondo player groups (7–9, 10–11, 12–13, 14–17, 18–32, and 33+ years) and discovered differences in agility performance between groups. In addition, according to Jakovljevic et al.(2012), in their study on 12-14 year-old basketball players, the T-test and Basketball zigzag agility test of the 14-year-old group were found to be better than those of the 12-year-old group. These studies indicate that agility in general and sport-specific agility increases with age during preadolescence and adolescence. There were considerable differences in agility between the different age groups. The results of this study support these findings by showing that agility and TSAT performances of taekwondo players also increase with age, and that there are performance differences between ages.

Our results also support the findings in the literature that SLJ distance increases with age (Castro and Ortega, 2010). In this study, the SLJ values of the 13-15 age group athletes were found to be significantly higher than the 11-12 age group. Loursen et al. found that SLJ values increased more rapidly between the ages of 12-14 years, with the largest increase occurring between 10-13 years (Kelly, 2022). In another study, Ramirez et al. (2017) reported significant differences in long jump results between the ages of 9 and 18, with the greatest improvement observed between the ages of 9-13.

The results indicated that TSAT was positively and highly correlated with the zigzag test (r-value:0.79) among 11-12-year-old players. The correlation was moderately negative between TSAT and SLJ (r = -0.60) in 11-12 year-old players. In addition, no significant relationship was found between SLJ and zigzag test performance. On the other hand, TSAT was moderately correlated to ZT and SLJ (r-values:0.60 and -0.53, respectively) in the 13-15 years old players. Contrary to the 11-12 age group, there was a significant negative correlation between the SLJ and ZT (r = -0.65) in the 13-15 age group. The results indicate that the taekwondo-specific agility performance, zigzag agility performance, and explosive strength are interrelated. Explosive strength, acceleration, and deceleration over a short time are the main components of taekwondo. These tests evaluate the explosive strength and agility performances of 11-12 and 13-15-year-old players with varying complexities: acceleration, body movement control, and coordination. Although there was an age difference between the groups, a correlation was found between all the tests. Therefore, the values of the correlation coefficients between the tests indicate that all three tests compare similar qualities. Fiorilli et al. also found a high correlation between agility tests in players in each age group(U12-U14-U16-U18) between the ages of 12-18 (Fiorilli, 2017). Studies in the literature have compared general agility tests with specific agility tests. Jakovljevic et al.(2012) found a significant correlation between the agility t-test and the specific basketball test in basketball players aged 12 and 14. In addition, Jones et al.(2013) reported a significant correlation between SLJ and agility t-test for the 11-12 age group. Moreover, another study reported a moderate negative correlation between TSAT and SLJ and a positive high correlation between TSAT and agility t-test. These findings suggest that training the horizontal jump force in taekwondo athletes could increase their agility performance (Chaabene, 2018; Brughelli, 2008).

CONCLUSION

This study compared the agility performance of taekwondo athletes in the 11-12 and 13-15 age groups and evaluated the differences. The findings of this study are similar to those in the literature (Castro, 2010; Kelly, 2022; Fiorilli, 2017; Avcı, 2021). In addition, this study helps to better understand the development of taekwondo-specific agility with age. TSAT performance and zigzag agility test performance both increased with age among taekwondo players aged 11-12 and 13-15 years old taekwondo players. This may be due to the physical features of the 13-15 age group and the fact that the strength is more developed than the 11-12 age group. TSAT appears to be more sensitive and can better distinguish differences among players. Therefore, although there was not much difference in years of experience between the groups, a significant difference was found in their TSAT test performances. Due to the better correlation between zigzag agility and SLJ performance in the 13-15 age group, SLJ and agility training could improve taekwondo-specific agility. On the other hand, taekwondo players aged 11-12 can improve their performance more with ZT and TSAT agility exercises than SLJ exercises.

Limitations of the study

A limitation of this study was that the genders of the athletes in the sample group were not evaluated separately.

AUTHOR CONTRIBUTIONS

Conceptualization: Berk Avci and Aksel Celik. Data curation: Berk Avci. Formal analysis: Berk Avci and Aksel Celik. Investigation: Berk Avci. Methodology: Berk Avci and Aksel Celik. Project administration: Berk Avci. Resources: Berk Avci. Supervision: Berk Avci. Validation: Berk Avci. Visualization: Berk Avci. Writing – original draft: Berk Avci and Aksel Celik. Writing – review & editing: Berk Avci and Aksel Celik.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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ORIGINAL ARTICLE

Is there a relationship between the motivation of female fitness practitioners and tobacco and alcohol consumption? Perspectives for improving lifestyle for health

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ABSTRACT

The practice of Physical Exercise has been associated with the adoption of healthy lifestyles and, consequently, an improvement in health. The objective of the study was to investigate whether there is a relationship between tobacco and alcohol consumption and the type of modality practiced; and if the reasons presented for the practice are somehow related to these habits. The sample consisted of 177 adult women, who practice Fitness, divided into 3 groups: 68 practitioners of high intensity modalities, 54 of Zen modalities, and 55 of modalities of both types (mixed group). The Exercise Motivation Inventory 2 was used to assess the reasons for the practice of Physical Exercise. Relating smoking and alcoholism habits with the reasons for the practice, significant positive correlations were found between: smoking habits/affiliation (p = .037); alcohol consumption/keeping healthy (p = .035). Significant inverse relationships between: number of cigarettes smoked per day/weight management (p = .000); number of cigarettes smoked per day/health (p = .048). Class 3 of women who quit smoking had statistically significant higher scores on disease (p = .012) and staying healthy (p = .001). Affiliation is a common reason for smoking and exercising; those who smoked for a longer period of time seem to resort to the practice for reasons relating to the onset of illness or to maintain their health. Women who don't drink seem to be more concerned about their health than women who do drink. Clarifying these relationships is essential for creating more effective intervention programs to eliminate/reduce tobacco and alcohol consumption and their harmful effects on health.
Keywords: Physical activity psychology, Physical exercise, Exercise psychology, Woman's health, Lifestyle, Tobacco consumption, Alcohol consumption.

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INTRODUCTION

The concept of lifestyle has gained considerable importance in recent decades (Shephard, 1996; Pieron, 2004). According to the World Health Organization (WHO) (WHO, 2004; Portes, 2014) lifestyle consists of a "*set of habits and customs that are influenced, modified, encouraged or inhibited by the prolonged process of socialization*". These habits and customs include the use of substances such as alcohol, tobacco, tea or coffee, dietary and exercise habits. These have important health implications and are often the subject of epidemiological investigations (Pieron, 2004).

It is unanimous in the literature that lifestyle is the main risk factor for chronic non-communicable diseases, such as diseases of the circulatory system, cancers, respiratory diseases and diabetes mellitus (WHO, 2011; WHO, 2014; Araújo et al. , 2017; Kaczynski et al., 2008; Macedo et al., 2003; Ferrari et al., 2017), being also responsible for a large part of deaths from cardiovascular diseases in the world, so its measurement and monitoring can contribute to the definition of strategies and actions to combat the adoption of risk behaviours, disease prevention and health promotion (Ferrari et al., 2017).

Tobacco and alcohol consumption are two very worrying risk behaviours that compromise health. WHO data on global tobacco trends indicate that in 2021 there are 1.3 billion tobacco users worldwide and alcohol consumption is associated with more than 740,000 cases of pharyngeal, laryngeal or liver cancer (Pan American Health Organization, 2021; UN, 2021). In Portugal, data from the National Statistics Institute (INE) indicate that in 2019, 17% of the population over 15 years old were smokers (14.2% smoked daily and the remaining 2.8% smoked occasionally) and 21, 4% ex-smoker (SNS, 2020). The data also indicate that the percentage of women who say they have never smoked, 75.3%, is much higher than that of men in the same condition, 44.8%. Regarding the consumption of alcoholic beverages, the survey reveals that 29.6% of the population over 15 years of age consumed alcoholic beverages daily, 31.4% consumed regularly, but not daily, and 17% only occasionally. The percentage of men who report consuming alcoholic beverages daily, 40.3%, is also much higher than that of women, where more than half indicate that they do so occasionally.

The literature has advanced that smokers are more likely than non-smokers to engage in other risky behaviours (Kaczynski et al., 2008). There is consensus that the lack of PE associated with smoking increases the likelihood of people developing cardiovascular, cerebrovascular, chronic respiratory diseases and cancer (Rodrigues et al., 2008). On the other hand, regular physical activity has been linked to reduced smoking levels (Kaczynski et al., 2008; Billerbeck et al., 2019; Daniel et al., 2007), probably because the two behaviours provide similar rewards, such as a temporary decrease in stress and an improvement in mood (Kaczynski, 2008). In fact, in 60% of the studies included in the systematic review by Kaczynski et al. (2008), composed of 50 articles related to the topic, an inverse relationship between smoking and PE was reported (Lima and Macedo, 2012). Exercise intensity and its effect on the desire to smoke and abstinence have also been the subject of research interest, and the results are more visible for more intense exercises (Lima and Macedo, 2012; Taylor and Katomeri, 2007; Smits et al., 2016). Therefore, when combined, the variables type of training and intensity may potentiate the elimination of this risk behaviour (Daniel et al., 2007; Smits et al., 2016; Trevisan, 2019).

Abusive alcohol consumption becomes a concern, not only because of the damage it causes to metabolism, neural function, cardiovascular system and thermoregulation (NIAAA, 2010; Vella and Cameron-Smith, 2010; Giacomelli et al., 2019), but also because it is consumed earlier and in different environments, such as sports (Giacomelli et al., 2019; Haugvad et al., 2014; Oliveira et al., 2014). This habit in the sports environment has been justified by commemorative reasons, socialization, tension relief, stress relief, functioning as an anxiolytic (Martens et al., 2005; Nery, 2015). PE practitioners in the gym have also shown inappropriate behaviour regarding the use of alcoholic beverages (Oliveira et al., 2014). For example, in a study carried out by Oliveira, Liberali and Coutinho (2012), of the 40 women practitioners of Fitness that made up the sample (ranging the practice time between 6 months and 3 years), 50% consumed between one and three drinks per week. Later Oliveira et al. (2014) added that although PE practitioners in the gym showed risk behaviour for alcohol consumption, there was no association between training intensity and that behaviour. What is known is that individuals who report moderate or frequent consumption, but not dependent, may have more abdominal and peripheral fat than non-consumers (Oliveira et al., 2014; Toffolo et al., 2012). In addition, the consumption of alcoholic beverages can interfere with the absorption of nutrients important for increasing muscle mass, cause dehydration because it is a diuretic (Oliveira et al., 2014; Suter, 2005) and compromise muscle strength, power and endurance (Oliveira et al., 2014; ACSM, 1997).

However, while women in Portugal tend to consume less alcohol and tobacco, they also tend to adopt less exercise behaviours, as, according to data published by the SNS (2020), 69% of women say they do not practice physical exercise. (EF) and 13.8% of those who practice do it only twice a week (SNS, 2020). In order to enhance the involvement and adherence of women to the practice of Exercise, it is essential that they practice activities that meet their motivations (Box et al., 2019). In fact, women have shown more participatory reasons for aesthetic issues, social interaction, revitalization, fun, challenge, stress regulation, pleasure, agility, positive health and improvement of physical condition (Box et al., 2019; Valim and Volp, 1998; Liz et al., 2013; Klain et al., 2013; Serrano, 2005). The reasons have varied, for example, depending on the sport practiced (Box et al., 2019; Heinrich et al., 2014; Fisher et al., 2017) and the age of the practitioners (Constantino, 1998; Moutão, 2005).

Creating intervention programs through the promotion of PE, reduction or elimination of tobacco and alcohol consumption is essential to promote healthier lifestyles.

Therefore, this study aims to: i) characterize the smoking and alcohol habits of women who practice Fitness; ii) verify if smoking and alcohol habits differ according to the type of exercise practiced in a Fitness context; iii) verify if smoking and alcohol habits are related to the reasons presented for the practice of PE in a Fitness context.

METHODOLOGY

Sample

The sample consisted of 177 female practitioners of gym activities, aged between 18 and 70 years (42.3 ± 12.9) and mean practice time of 8.5 years (± 8.0). Most of the elements in the sample practice between once or twice a week (n = 113, 63.8%), reside in the city of Viseu (n = 120, 90.2%), are licensed (n = 59, 62.9%) and are teachers (n = 34, 25.8%).

The following inclusion criteria were selected in the sample: only female fitness practitioners, aged over 18 years and a minimum practice time of 6 months.

Participants were grouped into high-intensity (HI) modalities practitioners (n = 68, 38.4%), Zen practitioners (ZG) (n = 54, 30.5%), and mixed practitioners (MG) (n = 55, 31.1%). High-intensity modalities included high-impact modalities, such as Cardiofitness, Bodybuilding, Functional Training, Jump, GAP, Dance Classes, Body Pump, Localized, Body Combat, Body Attack, Cycling, TRX, Cross Training and Body Step. In Zen, low-impact modalities with a more meditative component were included, such as Yoga, Pilates, Body

Balance, Stretching and Tai Chi. The third group, that of mixed training practitioners, was created by the fact that there are women who practice modalities from both groups mentioned above. The modalities were grouped in this way according to the methods of estimating intensity of cardiorespiratory and resistance exercise suggested by the ACSM (2018). That is, in the first group, HI, are included modalities whose intensity can vary between 60 and 89% of the Heart Rate Reserve (HRR), 64 to 90% of VO_{2max}, perceived exertion from 14 to 17 points (rating on 6-20 RPE scale), therefore, vigorous intensity; the second group, ZG, the intensity of the modalities can vary between 30 to 39% of the HRR, 37 to 45% of VO_{2max}, perceived exertion from 9 to 11 points, therefore, light intensity. The third group, MG, as it encompasses practitioners of both types of modalities, the intensity can range from light to vigorous.

Procedures and Instruments

After explaining the purpose of the study, what their participation consisted of, as well as guaranteeing the confidentiality of their responses and that they could withdraw at any time, the volunteers were asked to sign an informed consent statement. Before the practice of their activity, each study participant was invited to fill, individually, 2 questionnaires: (1) questionnaire (own source) for the characterization of the sample that included questions such as: age; the profession; literary qualifications; practice time; the number of weekly workouts; the modalities practiced and the smoking and alcoholic habits. Regarding smoking, it was asked if the practitioners at the time of answering were smokers and if so, how many cigarettes they consumed per day; if not, if they had ever smoked; for how long; how many cigarettes they smoked per day and how long ago they stopped smoking. They were also asked if they consumed alcoholic beverages and, if so, a scale was used for the amount: Less than 7 drinks per week; between 7 and 14 drinks per week and more than 14 drinks per week. (2) Exercise Motivation Inventory 2 (EMI-2) (Markland and Ingledew, 1997), Portuguese version consisting of 51 questions (Alves and Lourenço, 2003), which allows assessing the reasons for the practice of Physical Exercise. This questionnaire is organized into 5 dimensions: Psychological Motives; Interpersonal Motives; Health reasons; Body-related and Physical Condition Reasons. Each of these dimensions encompasses 3 or 4 specific reasons, and in total 14 reasons are presented, and they are: Pleasure; Challenge; Social Recognition; Affiliation; Competition; Health; Illness; To stay healthy; Weight; Appearance; Strength/Endurance; Agility; Stress; revitalization. Each reason consists of 3 or 4 items, rated on a 6-point Likert scale (0- not at all true for me; 5- completely true for me). In the answers to this questionnaire, Cronbach's Alpha was applied, and the results were greater than 0.6, guaranteeing the reliability of the answers.

Statistical analysis

Statistical procedures were performed using the SPSS program, version 25, through descriptive statistics of the questionnaire scores. Descriptive statistics provided simple summaries of the sample by calculating measures of central tendency, such as mean and standard deviation. The normality of the sample was verified through measures of Asymmetry and Kurtosis in the continuous variables, having verified that only the variable “*number of cigarettes per day*” did not present normal distribution, we opted for non-parametric statistics. ANOVA was used for the variables with normal distribution, for the others the Kruskal-Wallis test was used. To verify which groups there were differences in, Pairwise comparisons were used. Spearman's correlation was used to assess the relationship between the variables “*number of cigarettes per day*” and participatory motives. To assess the relationship between parametric variables and participatory motives, Pearson's correlation was used.

It should also be noted that for the analysis of participatory motives, the age difference was controlled, since some discrepancy was observed between the average ages of the sample groups.

RESULTS

The characteristics and smoking and alcohol habits of the participants according to the modality practiced are presented in Table 1.

Table 1. Descriptive characteristics of the participants.

	High Intensity (a)	*Zen* (b)	Mixed (c)	Total	*p*
Age (years)[1]	38.2 ± 10.9	49.1 ± 13.1	45.0 ± 13.5	42.3 ± 12.9	.000*
Practice time (years)[1]	8.9 ± 5.8	5.8 ± 5.5	12.3 ± 10.1	8.5 ± 8.0	.000*
Weekly Frequency (freq, %)[2]					
1 to 2 times a week	35, 51.5%	54, 100.0%	24, 43.6%	113, 63.8%	.000*
3 to 4 times to week	20, 29.4%	0, 0.0%	21, 38.2%	41, 23.2%	
5 or more times a week	13, 19.1%	0, 0.0%	10, 18.2%	23, 13.0%	
Smoking Habits (freq, %)[2]					
Smokers	8, 11.9%	0, 0.0%	8, 14.3%	16, 11.3%	.246
Stopped smoking	14, 31.1%	5, 33.3%	16, 43.2%	35, 36.1%	.508
Alcohol consumption (freq, %)[2]					
Consumers	22, 33.3%	5, 27.8%	22, 40.0%	49, 35.3%	.580
Less than 7 drinks per week	20, 100.0%	5, 100.0%	20, 95.2%	45, 97.8%	.544
More than 14 drinks per week	0, 0.0%	0, 0.0%	1, 4.8%	1, 2.2%	.544

*Note. [1]ANOVA [2]Chi-Square. Age – a < b; a < c; b > c. Practice time – a > b; a < c; b < c. *p ≤ .05.*

As previously mentioned, the age of the sample varies between 18 and 70 years, with the ZG having a higher average age than the other groups and the group with younger elements being the HI group. The practitioners of the MG are those who have been practicing for the longest time and those in the ZG have been practicing for the least. Regarding the weekly frequency, most of the sample practices once or twice a week (n = 113, 63.8%), in fact, the entire ZG presents this weekly frequency. With regard to smoking habits, 88.7% of the sample are non-smokers and 36.1% have stopped smoking, with the MG having the highest percentage of smokers and ex-smokers. Alcohol consumption is also mostly found in MG practitioners and in greater amounts. It is also important to mention that the consumption of alcohol by these practitioners is not considered abusive, as 97.8% consume less than 7 drinks per week.

It appears that there are no statistically significant differences between the fact of being smokers or ex-smokers and the type of exercise practiced. The same is true of alcohol consumption, regardless of the amount.

Figure 1 shows the distribution of the number of cigarettes consumed per day as a function of the type of sport practiced.

In this variable, the distribution is not normal, the daily consumption of cigarettes varies between 1 and 40, although the mean and standard deviation is 10.9 ± 9.71. There are 2 individuals who practice HI modalities who are out of the standard indicating that they consume 40 cigarettes a day. Even so, it is the practitioners of the MG who consume more cigarettes per day.

Table 2 shows the distribution of the number of years of smoking and the number of years that stopped smoking according to the type of modality practiced.

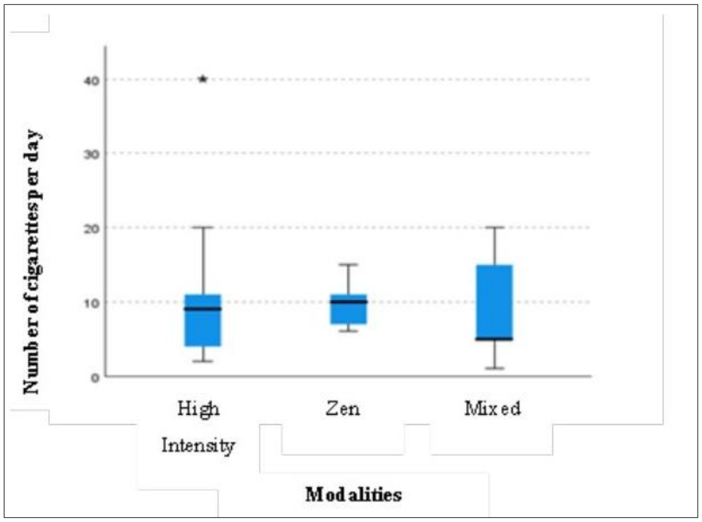

Figure 1. Number of cigarettes consumed per day according to the type of sport practiced.

Table 2. Differences in time spent as a smoker and in time that quit smoking as a function of the type of modality practiced (mean ± standard deviation).

	High Intensity (a)	Zen (b)	Mixed (c)	Total	*p*	n^2_p
Number of years smoked	5.75 ± 5.30	6.80 ± 7.60	9.44 ± 6.71	7.29 ± 6.26	.432	0.072
Number of years quit smoking	11.39 ± 9.39	13.00 ± 9.09	20.90 ± 11.10	15.02 ± 10.63	.085	0.179

*Note. *p ≤ .05.*

Table 3. Characterization of the reasons for the practice (mean ± standard deviation).

Dimensions/Motives	Mean ± Standard Deviation	Asymmetry	Kurtosis
Psychological reasons	3.68 ± 0.72	-0.44	-0.31
Stress	3.59 ± 0.90	-0.28	-0.83
Revitalization	4.24 ± 0.76	-1.06	0.57
Pleasure	3.99 ± 0.95	-0.97	0.51
Challenge	2.88 ± 1.12	-0.22	-0.76
Interpersonal motives	1.72 ± 1.05	0.37	-0.78
Social Recognition	1.06 ± 1.15	0.89	-0.33
Affiliation	2.38 ± 1.33	-0.09	-0.94
Competition	1.73 ± 1.32	0.33	-0.93
Health reasons	3.46 ± 0.69	-0.10	-0.44
Health	1.98 ± 1.39	0.22	-0.89
Illness	3.92 ± 0.91	-0.70	-0.05
To stay healthy	4.49 ± 0.60	-1.44	2.10
Related reasons with the body	3.16 ± 1.08	-0.45	-0.29
Weight	3.32 ± 1.23	-0.61	-0.38
Appearance	2.99 ± 1.14	-0.53	-0.12
Physical condition reasons	4.07 ± 0.71	-0.62	0.07
Strength/Endurance	4.04 ± 0.81	-0.79	0.19
Agility	4.11 ± 0.79	-1.19	2.20

Analysing the differences in the number of years in which they were smokers depending on the type of modality practiced, no significant differences were found between the practitioners of the 3 groups. The same happened with the number of years in which they stopped smoking.

Table 3 presents the reasons given by the participants of the sample for the practice of PE.

It appears that the practitioners in the sample indicate more Psychological Reasons (stress, revitalization and pleasure), Health Reasons (illness and keeping healthy), Body-related reasons (weight) and Physical Condition Reasons (Strength/Endurance and Agility) for the practice of PE. The least mentioned reasons were Challenge, Health, Appearance and Interpersonal Motives (Social Recognition, Affiliation, Competition).

The correlations between the reasons for the practice of PE and the smoking and alcohol habits of the practitioners of this sample were analysed. The results are shown in Table 4.

Table 4. Relationship between reasons for the practice and consumption of tobacco and alcohol (r-values).

	Smoking Habits	**Alcoholic Habits**
Psychological reasons	0.055	0.075
Stress	-0.003	-0.039
Revitalization	0.050	0.105
Pleasure	-0.001	0.093
Challenge	0.088	0.093
Interpersonal motives	0.040	0.025
Social Recognition	-0.085	-0.013
Affiliation	0.176*	0.092
Competition	-0.005	-0.027
Health reasons	0.052	0.075
Health	0.070	0.037
Illness	0.046	0.040
To stay healthy	-0.012	0.179*
Related reasons with the body	-0.052	0.030
Weight	-0.051	0.008
Appearance	-0.036	0.050
Physical condition reasons	-0.018	0.108
Strength/Endurance	-0.015	0.122
Agility	-0.018	0.065

*Note. * Significant correlation at the .05 level. **Significant correlation at the .01 level.*

Significant correlations ($p \leq .05$) were observed between Smoking Habits and Affiliation ($p = .037$), indicating that women who reported smoking were also the ones who were most likely to indicate Affiliation as the reason for the practice of PE; and between the consumption of alcoholic beverages and the reason to Keep Healthy ($p = .035$), in which women who said they did not drink more often indicated "*Keep healthy*" as the motivation to practice PE, when compared to those who said they did not drink. We also analysed the relationship between the quantities, whether the number of cigarettes consumed per day or the number of alcoholic beverages consumed per week, with the reasons for practicing PE, and significant, inverse relationships were identified between the number of cigarettes consumed per day and the reason "*Health*" (r = -0.376*, $p = .048$), indicating that women who consume more cigarettes per day are the ones who least indicate "*Health*" as the reason for the practice of PE; and between the number of cigarettes smoked per day and the reason "*Weight Management*" (rô = -0.797**, *p* = .000), with those who consume the most cigarettes least likely to pick "*Weight Management*" as a reason to practice.

Regarding the analysis of women who reported having stopped smoking, it was found that for the variable "*How long did they smoke*" three classes were constructed, corresponding to the number of years that the participants in the sample had been smokers. The first class included a duration of less than or equal to 5 years; the second class, between 6 and 9 years old; and the third class greater than or equal to 10 years. Analysing the reasons for the practice of PE, it was found that there were statistically significant differences in "*Disease*" (*p* = .012), in "*Keep healthy*" (*p* = .001), between the classes described above. The variables "*Psychological Reasons*" and "*Health Reasons*" are on the threshold of significance (*p* = .057 and .087 respectively), that is, there is no statistical evidence that the variables take different values for the different duration classes. Analysing the reason "*Illness*" by the classes of the variable "*duration*", it was verified that the existing differences are between the first and the third class, and those who smoked for less years presented lower values for this reason, therefore, those who smoked for a longer period more often selected "*Illness*" as the reasons for the practice of PE. Regarding the reason "*Keep healthy*", statistically significant differences were also found between the same groups, with the reason "*Keep healthy*" being more indicated by women in class 3, that is, those who smoked for longer were most likely to choose "*Stay healthy*" as the reason for the practice of PE.

DISCUSSION

Since physical inactivity, tobacco and alcohol consumption are modifiable factors (Ferrari et al., 2017), it is important to study effective ways to change these risk behaviours. Analysing the reasons given by women for the practice of Fitness modalities and involving them in this practice can be a good strategy to combat sedentary lifestyle. The women in the present study feel more motivated to practice PE for revitalisation; stress management; for pleasure; to stay healthy or through illness; to improve their Physical Condition, strength/endurance and agility. These results are in line with what has been advanced by several authors (Liz et al., 2013; Klain et al, 2013; Serrano, 2005) who report that women tend to exercise more to improve their Physical Condition; for health-related issues; stress management; revitalisation and for aesthetic reasons, mainly related to weight loss. The women in the present study also indicate reasons related to the body, mainly weight management, as important for the practice of PE, however, these do not seem to be the main reasons.

PE has been considered a strong ally in the fight against smoking (Rodrigues et al., 2008; Billerbeck et al., 2019), as it is believed that those who exercise regularly tend to reduce or stop using tobacco (Billerbeck et al., 2019). In fact, of the 177 women that make up the sample of the present study, 16 are smokers and 35 have stopped smoking. Given that the average practice time is 8.5 years, it is possible that PE has helped to stop this habit. However, although no statistically significant differences were found between smoking and alcohol habits and the type of exercise practiced by these women, in a study developed by Taylor and Katomeri (2007) it was found that just 15 minutes of walking not only reduced the smoking cravings, as well as withdrawal symptoms and time between cigarettes smoked. On the other hand, high-intensity aerobic exercise has been more effective in reducing withdrawal symptoms and the desire to smoke in the process of eliminating tobacco consumption, when compared with light and moderate exercise (Trevisan, 2019; Ussher et al., 2009; Roberts et al., 2015). In a study developed by Lima and Macedo (2012), an inverse relationship was observed between high-intensity PE and mild tobacco dependence. Alcohol abuse does not seem to be influenced by training intensity (Oliveira et al., 2014; Nery, 2015) leading to the belief that this behaviour does not differ depending on the type of modality practiced, as happened in the present study and in the study developed by Oliveira et al. (2014).

Through the analysis of the correlations between smoking and alcohol habits and reasons for the practice of PE, statistically significant relationships were found between tobacco consumption and Affiliation, suggesting the reason is common for the adoption of both behaviours. According to Bonilha et al. (2013) adults tend to smoke more for several reasons, including affiliative attachment, unlike younger adults who have higher scores for social smoking. These data are in agreement with the results of the present study since the average age of the participants is 42.3 years.

The consumption of alcoholic beverages showed a significant relationship with the reason "*Keep healthy*", that is, women who claim not to consume alcohol indicated that reason more than those who admit to drinking. As a primary effect of alcohol intake, there is a reduction in the activity of the central nervous system (Giacomelli et al., 2019). Physiologically, it is known that alcohol consumption causes damage to metabolism, neural function, cardiovascular and thermoregulatory systems (Vella and Cameron-Smith, 2010; Giacomelli et al., 2019). However, according to Martens et al., (2005) the consumption of alcoholic beverages may be related to the relief of tension, of stress, that is, it may work as an anxiolytic. Santos and Tinucci (2004) add that, despite the literature pointing to numerous harmful effects of alcohol consumption on sports performance, when consumption is light or moderate it does not seem to interfere with practice. In a study carried out with 12 individuals, being 6 moderate consumers of alcoholic beverages and the other 6 non-consumers, it was found that the intake of small and moderate doses of alcoholic beverages did not cause a significant change in heart rate, blood pressure, ventilation, consumption of oxygen, exercise perception, lactate concentration or work capacity (Nery, 2015). However, despite the frequent evidence of exaggerated consumption of alcoholic beverages by gym goers (Oliveira et al., 2014; Nery, 2015; Souza and Folador, 2020), the consumption presented by the participants of the present study is not considered abusive, since most consume less than 7 drinks per week, so in this sample it should not be considered a risky behaviour. Abusive consumption is considered when a woman consumes 4 or more doses of any alcoholic beverage in a single moment, or more than 7 doses per week (Souza and Folador, 2020). Apparently, quantity and regularity may be responsible for the harmful effects of consuming alcoholic beverages on health.

There were also statistically significant, but inverse, correlations between the number of cigarettes smoked per day and the reasons "*Health*" and "*Weight management*", which suggests that women who smoke more are less concerned with health and with the weight management. In fact, if women who smoke less seem to be more concerned about their health than those who smoke more, this effect may also be associated with the practice of PE as a determining factor in the set of health behaviours. A vast literature has shown that there is an inverse relationship between the practice of PE and tobacco dependence (Billerbeck et al., 2019; Lima and Macedo, 2012; Vella and Cameron-Smtih, 2010) so it is believed that the practice of PE decreases tobacco use, helping to prevent its harm (Billerbeck et al., 2019). For example, in a study carried out in London with pregnant women and smokers, when subjected to a 20-minute light to moderate intensity training program, a significant reduction in smoking cravings was found, as well as a decrease in some symptoms such as irritability, depression, tension, restlessness, and difficulty concentrating (Pomerleau et al., 2000). Another study, developed by Bess et al. (1999) demonstrated that a supervised intense exercise program was associated with long-term maintenance of women's tobacco cessation (Daniel et al., 2007). From the above, it appears that the tendency for those who practice PE is to reduce or eliminate tobacco consumption and, although there is no reference on the number of cigarettes smoked before practicing PE, the reality is that 36.1% of the members of the sample are ex-smokers and 11.3% are smokers. As for "*Weight management*", as mentioned, this reason is also more indicated by women who smoke less, although, of course, they know that PE is a strong ally in weight regulation and weight loss (Lima and Macedo, 2012). On the other hand, if your goal is to reduce or eliminate tobacco consumption, the literature suggests that PE is a way to mitigate the weight gain associated with this phase (Daniel et al., 2007).

Finally, regarding the women who reported having stopped smoking, the correlations between the duration of the behaviour and the reasons given for the practice of PE were analysed. It was found that women who smoked longer (class 3) were more likely to select "*Illness*" and "*Staying healthy*" as reasons for the practice of PE than those who smoked for less time (class 1). It is possible that class 3 women, that is, those who smoked for 10 or more years, are now aware of the harmful effects of tobacco and, therefore, have stopped smoking and resort to PE to stay healthy, or, on the other hand, it is also possible that they have contracted, or worsened, an illness and use PE to improve their health and prevent illness. In fact, smokers and individuals who have stopped smoking, but whose health has already been affected by tobacco use, tend to decrease their average life expectancy by 10 years, when compared to those who never smoked (Trevisan, 2019). However, quitting smoking after the age of 35 helps to regain two to three months of healthy life expectancy for each smoke-free year; in addition to that, after 12 months of cessation, it reduces cardiac risks by 50%; the frequency of exacerbations in patients with chronic obstructive pulmonary disease and decreases stress levels and mood disorders (Trevisan, 2019). And, if on the other hand, the practice of PE helps, for example, in reducing blood pressure, insulin resistance, helps in bone mineralization, improves the cardiorespiratory system, prevents hypertension and significantly prevents cardiovascular diseases (Rodrigues et al., 2008; Billerbeck et al., 2019), it is justifiable that these women, who smoked for so long, find in PE a way to improve their health-related life habits, since the age factor also has an impact being associated with the adoption of healthier lifestyles, due to the emergence or worsening of diseases and greater concern for health (Ferrari et al., 2017; Constantino, 1998; Moutão, 2005). It is also important to add that PE tends to improve the quality of sleep in the general population. This is affected by tobacco consumption due to nicotine addiction. Purani et al., (2019) found that increased daily exercise in smokers is associated with improved sleep quality.

CONCLUSIONS

The present study was developed with the intention of contributing, essentially, to the adoption of healthier lifestyles. It was developed with practitioners of female gym modalities, which is thought to be an added value, especially because in our country women are largely more sedentary than men, and it is essential to create programs to promote PE that evolve them and range from meeting their motivations, contributing to the initiation and adherence to the practice. With adherence to exercise, there will be a greater tendency to reduce or stop other risk behaviours, such as tobacco and alcohol consumption. But, if, on the one hand, the type of sport practiced seems to be unrelated to these habits, Affiliation is a common reason for tobacco consumption and for the practice of PE. Health and weight management reasons also appear to be less prevalent when tobacco consumption is higher. On the other hand, the motivation to practice for reasons of illness and health maintenance seems to be higher in women who smoked for more years.

It is important to mention that the present study was developed with practitioners of fitness modalities in which the practice time factor can influence the results. The fact that a wide range of ages was used may be considered a limitation of the study to be taken into account in future studies. Another issue that seems to be interesting to clarify in future investigations is the reasons that lead fitness practitioners to maintain tobacco and alcohol consumption. Perhaps by reversing the line of thought, we can understand how these behaviours and intervention programs can be more effective.

In short, if the literature has shown that lifestyle interventions are as effective as evidence-based medical therapies in reducing mortality, it is essential to contribute to the design of these intervention programs.

AUTHOR CONTRIBUTIONS

Sousa P., participated in the manuscript design, data analysis and interpretation, and wrote the manuscript. Coelho E., participated in the analysis and interpretation of data. Mota M., participated in the critical revision of the content.

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ORIGINAL ARTICLE

Prevalence and attitudes towards nutritional supplements use among gymnasium goers in Eldoret Town, Kenya

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ABSTRACT

Active people in sports or regular exercises make up a significant portion of individuals using nutritional supplements (NS). Therefore the purpose of this study was to investigate the prevalence of NS (types, sources of information), motives for going to the gym, reasons for consumption of nutritional supplements and attitudes towards nutritional supplements among gymnasium users in Eldoret Town, Kenya. Data was collected using a questionnaire from 210 participants who were sampled through systematic convenience sampling from 11 gyms in Eldoret Town, Kenya. The study found that majority (55.3%) of the respondents used nutritional supplements and most of them used the supplements believing that they enhance their performance at the gym and therefore perceived usage of supplements as acceptable. The major reasons for going to gym were to enhance health, body building and to stay fit. Most (91%) of the gym users got the information about NS from the internet and the most consumed NS were protein supplements (72%), followed by sport drinks (69%) and fish oils (60%). It is concluded that gym goers use nutritional supplements and have positive attitudes towards their use. Therefore, this study recommends that users should be sensitized on the value, precautionary measures and side effects of using nutritional supplements.
Keywords: Physical activity psychology, Exercise psychology, Prevalence, Nutritional supplements, Gymnasium goers.

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INTRODUCTION

Dietary supplements refer to substance(s) besides tobacco that are aimed to enhance diet because of the presence of one or more dietary ingredients (Kenya Pharmacy & Poisons Board, 2012). These dietary ingredients include proteins, minerals, vitamins, hint and different elements presumably available in normal diet (Giammarioli et al., 2013). NS are commonly in form of tablets, pills, or powders. Today there is increase demand for dietary supplement among persons looking for alternative means to supplement their nutritional intake. Additionally, the high focus on dietary supplement by media, rigorous advertisement by NS manufacturers and suppliers, and influence of friends and families about dietary supplements influences their consumptions particularly among active individuals in sports or demanding physical activities such as gym goers (Goston & Correia, 2010).

Several reasons are behind the high demand for nutritional supplements. Some of the most cited reasons include increased performance, shorten recovery time, supplement nutrition, building muscles, reduce stress, and boost immunity (Dickson & Mackay, 2014; Miller & Welch, 2013). Today availability and ease of access of various nutritional supplements make them convenient to gym goers who are currently the major target after athletes (FAO, 2010; Rock, 2007).

Globally, the aspect of going to the gym and other fitness facilities is fashionable and currently is a multi-million-dollar industry and the physical activities offered in these facilities are used as a panacea to a myriad public health concerns. Kenyans are becoming more and more avid about their health which is attributed to present increase of gyms in the country (Otwona, 2013). People go to the gym for various reasons such as reducing their weight, to build muscles, maintain a healthy body, or for socialization purposes (Eliason, et al., 1997; McGinnis & Ernest, 2001; Stewart, et al., 2013; Thakur & Brar, 2018). However the above reasons are attributed to studies which have been carried out from the West and it will be apt to find out the reasons which spur gym attendance in Kenya.

The prevalence of dietary supplements consumption among gym users is on the rise as indicated by increased outlets such as pharmacies, cosmetic shops, and supermarkets (Mazzini et al., 2021; Rovira et al., 2013; Ruano & Teixeira, 2020; Senekal et al., 2019). Studies have shown that gym users' consumption for nutritional supplement is over 40% (Ruano & Teixeira, 2020; Senekal et al., 2019; Thakur & Brar, 2018) with some studies reporting prevalence higher than 60%. For example, Thakur and Brar (2018) found a prevalence of 70% among gym trainees in Punjab, India while Senekal et al. (2019) reported a prevalence of 81% in South Africa. Mazzini et al. (2021) found that 85.4% of the participants had used DS. However, there is consensus that the prevalence of DS could be determined by the local regulations, nutritional behaviours, social, economic level, or physical activity culture in particular region. As such it is apt to investigate the prevalence of DS use among gym goers in a rural setting of Eldoret dominated by the Kenyan long distance runners.

A multitude of studies have shown that many people using nutritional supplements hardly seek professional advice before using them (Jason, 2009; Tian, et al., 2009). Regrettably, consumption of nutritional supplements is pronounced among athletes and physically active non-athletes (Goston & Correia, 2010) and more aptly among the people who go to the gyms. In regard to the sources of information on dietary supplements, among Americans who used dietary supplements, 73% reported TV as the best source of information on NS followed by newspapers, radio, acquaintances and displays (Marinac et al., 2007). Other sources of information on NS include internet (Attlee et al .,2018;Kagiso ,2020;Muwonge et al.,2021;Thakur & Brar ,2018) family members (Attle et al .,2018 ;Harnack, et al. 2001), printed materials e.g. Journals, books, magazines (Harnack, et al. 2001 coaches/trainers (Muwonge et al., 2021) and food stores (Archer & Boyle, 2008; Dickinson, et al.,2014). However health care professionals such as nutritionists, dieticians, physiotherapists and pharmacists are rarely used as sources of information (Archer & Boyle, 2008; Attlee et al.,2018; Dickinson, et al.,2014). A study on DS uses among gym users in Nairobi found that nutritionists, doctors, sellers of nutritional supplements, peers, and gym trainers were among the perceived reliable source of information about supplements by users (Wachira, 2011). Creanor, et al. (2017) found that, prior to use, 41% of gym goers in Johannesburg always read the label on the nutritional supplements for information about benefits and contradictions of the nutritional supplement in question.

There are many supplements' brands and choices available in the market which varies from one region to the other. In the United States the commonly used DS include minerals, vitamins, and herbal products (Barnes, et al., 2010). In most European countries about 50% of nutritional supplements contain vitamins or minerals (European Food Safety Authority [EFSA], 2017). A study in Netherlands reported users and non-users of DS believed they are safe and they would only be harmful if the users take excessive dose or have contradicted medical condition (Pajor, et al., 2017). People further noted DS may negatively impact the natural body functions but consumers are aware of the risks (Pajor, et al., 2017).Therefore it is important to establish the kinds of DS which are consumed by gym goers in Eldoret, Kenya.

Social demographic status such as gender, age, education, and marital status may influence the use of DS (Radimer et al., 2004). For example, gender has been found to be a predictor of DS use with women plausibly uses DS than men (Foote et al., 2003; Jawadi et al., 2017; Ruano & Teixeira, 2020; Shariff, et al., 2018; Stefan, 2015). Nutritional supplement usage is reported to increase with age with more than half of Americans older than 65years, taking multivitamin or other nutritional supplements regularly as compared to younger adults (Hollenstein, 2007). In Canada, age was also closely related to supplement use as utilization rose steadily among women (60%) and in men (40%) aged over 51 years (Vatanparast, et al., 2010).

In Kenya, nutritional supplements are now common with all indicators (their presence in pharmacies, supermarkets, cosmetic shops) showing increased consumptions by many Kenyans (Wachira, 2011). Studies have shown that most of the users in Kenya are athletes and gym goers (Kimiywe & Simiyu, 2009; Wachira, 2011). Available evidence reveals gym users depend more on trainers than dieticians on advice about nutritional supplements (Attlee et al., 2018). The danger is that majority of trainers lack adequate knowledge on DS to recommend the right and safe nutritional supplements. Therefore, this study investigated the reasons for going to gym, the reasons for using nutritional supplements and the type of nutritional supplements used among the gym users in Eldoret town. The findings provide information to stakeholders in the fitness industry which can form the basis for policy formulation on regulating the use of nutritional supplements in the country. Indeed, some of the DS are laced with contaminated or banned substances which could be a precursor to the many Kenyan athletes who have failed doping controls. Consequently, the findings of this study have monumental implications to the anti-doping agency of Kenya (ADAK) in their fight against doping in Kenya.

Theoretical framework

This study is underpinned in the Theories of Reasoned Action (TRA) (Ajzen & Fishbein, 1980) and Theory of Planed behaviour (TPB) (Ajzen, 1985). The goal of TRA is to predict and understand human behaviours. The theory suggests that humans are rational and have the capacity to use available information to make decisions that influence their behaviours. The theory further suggests human can refrain from behaviours if they are willing. It asserts that human behaviour is determined by the attitude towards the behaviour (personal factor) and subjective norms (interaction between persons perception of how relevant others such as friends perceive of their behaviours and the individuals drive to comply with significant others). In the present study, TRA helps to understand use of nutritional supplements among gym users, the motivation to conform with significant others to feel accepted, and behavioural intentions of the gym goers with regard to nutritional supplements (Ajzen & Fishbein, 1980). However, TPB included the concept of perceived behavioural control on the TRA to buttress the drive (intention) and capacity to initiate behaviour (behavioural control). This is anchored on perceived power or control which is determined by beliefs about the accessibility or inaccessibility or resources to support behaviours and perceived ability to control the impact of the response from the behaviour to support or inhibit the actions (Ajzen, 1985). Therefore, TRA and TPB help to predict behaviours and identify features that can guide educators assess the use of DS and design the right interventions by incorporating the theories constructs into behavioural model.

METHODS

Research design and Location of the study

The study adopted cross-sectional analytical research design. The study was carried out in Eldoret town, Kenya. Eldoret serves as the administrative centre for Uasin Gishu County and is the fifth largest town in Kenya. The town has a population of 475,716 inhabitants according to 2019 national census. Eldoret is the hometown of the renowned elite Kenyan runners (home of champions) and there are many training camps in the surroundings. Therefore, the area was ideal for the study as most of the athletes visit the gym for numerous exercises regimens. The study targeted all the gym users from the 15 gyms in Eldoret town. However, data was collected from 11gyms as gym managers of 4 gyms declined their clients to participate in the study. From the attendance registers it was established that the gyms had 40 frequent users on weekly basis.

Sampling size and Sampling techniques

Purposive sampling methods were utilized to select the gyms while systematic convenience sampling techniques were used to sample the gym goers to participate in the study. Through the assistance of fitness instructors, researchers were introduced to the gym goers. They were explained the purpose of the study and those who agreed to participate in the study were requested to sign informed consent forms. The informed consent indicated that the participants were free to pull out of the study, voluntary participation, refraining from questions which they were uncomfortable with and their responses were going to be used for academic purposes only. To participate in the study the individual had to be a regular gym member and attended the gym at least two or more times a week. Participants with medical/health conditions or illnesses requiring consumption of nutritional supplements were excluded from the study. A total of 199 gym goers took part in the study and their demographic details are presented in Table 1.

Research instruments

A self-administered questionnaire was used for data collection. The questionnaire had five sections where items in Section A sought demographic details of the respondents such as gender, age, and occupation. Section B had items related to exercising at the gym such as frequency of visiting the gym in a week, how long they had been going to the gym and purpose of going to the gym. Section C solicited for reasons for the consumption of nutritional supplements, sources of information, types and attitudes towards nutritional supplements. Items in section B were weighted on a five-point Likert scale, starting with strongly agree (SA) to Strongly Disagree (SDA).Items in Section C on reasons for consumption and attitudes towards nutritional supplements were weighted from strongly agree to strongly disagree. The items on sources of information, types and frequency of use of NS were weighted on Never (N) Rarely (R), Sometimes (S), Frequently (F) and Very Frequently (VF). Participants were asked questions on reading labels and the side effects of NS use. The validity of the instrument was ascertained by involving lecturers in exercise science, and physical trainers. The reliability of the instrument has been reported in previous studies of Coopoo, et al., 2020; Creanor *et al.*, 2017; Gabriel, et al., 2012). However Cronbach statistical test was computed and a reliability coefficient of 0.80 was realized and considered adequate for the study (Blaxter, et al., 2006).

Data collection procedure and Ethical considerations

Kenyatta university ethical review board (KUERB) Ref. no. pku/891/11952 approved the study protocol. Subsequently letters were written to the gym managers explaining the purpose of the study and were requested for access to their facilities for the study. After approval by the gym managers, the researcher visited the gyms in the evening. The researcher sought the respondents consent after explaining the importance of the study and then gave them sufficient time to accurately fill the questionnaire. The questionnaires were then collected for data entry and analysis.

Data analysis

Microsoft excel and SPSS were used to organize and analyse the data. Descriptive statistics of frequencies, percentages, means, and standard deviations were used to analyse the data and results were presented using tables.

RESULTS

Demographic characteristics

A total of 199 gym users were assessed in the study with 140 (29.64%) males and 59 (29.64%) females. Most 120 (60.4%) of respondents were aged between 26 and 35years while the least were aged between 21 and 25 years 39 (19.6%). In regards to their occupation there were trainers, medical officers, security, students and others. Majority 88 (44.2%) of the respondents had been going to the gym for a period of 1 – 2 years, one year 52 (26.1%), 3-5 years 38 (19 %) while those who had been going to the gym for more than 5 years 21 (10 %). In terms of weekly attendance to the gym most 74 (37.2% went more than three times, 58 (29.1%) visited twice, 46 (23.1%) thrice while 21 (10.6%) went once.

Regarding nutritional supplements use, 110 (55.3%) of participants used nutritional supplements while 89 (44.7%) did not use. Asked whether they were aware that nutritional supplements are prohibited 120 (60.3%) were affirmative for YES while 79 (39.7%) negated. The reasons for going to the gym are presented in Table 2.

Results in Table 2 show that the main motives for going to the gym of the participants were enjoyment and fun, medical advice, conditioning the body, cross fit training purposes and toning the body, while the least ranked motives were being with friends, staying healthy and for spiritual motives. The reasons for consumption of nutritional supplements are presented in Table 3.

Results in Table 3 show that the reasons for consumption of nutritional supplements of gym users were to assist in coping with stresses of muscle gains in the gym, to improve perform in the gymnasium, health and to reduce cravings in order to decrease body weight while the least ranked reasons were pressure from peers and to reach personal goals. The sources of information on nutritional supplements are presented in Table 4.

Table 1. Demographic characteristics (n = 199).

Demographic characteristics	F	%
Gender		
Male	140	70.4
Female	59	29.6
Age		
21-25yrs	39	19.6
26-30yrs	60	30.2
31-35yrs	60	30.2
36-40yrs	40	20.0
Occupation		
Trainer	60	30.2
Medical Officer	39	19.6
Security	40	20.1
Student	40	20.1
Others	20	10.0
Years in the Gym		
<1	52	26.1
1-2	88	44.2
3-5	38	19
>5	21	10
Weekly attendance		
Once	21	10.6
Twice	58	29.1
Thrice	46	23.1
More than thrice	74	37.2

Table 2. Reasons/motives for going to the gym among the users (n = 199).

I go to the gym...	Mean	Std. Deviation
For enjoyment and fun	3.93	.91
Following medical advice	3.84	1.09
Condition my body	3.82	1.25
Cross Fit training purposes	3.79	.98
Tone my body	3.78	1.20
To be healthy	3.78	1.02
Lose weight	3.71	1.35
Be with friends	3.62	1.26
Stay healthy	3.35	1.47
For spiritual motives	3.13	1.35

Table 3. Reasons for Consumption of Nutritional Supplements of Gym Users (n = 199).

I consume Nutritional Supplements in order to…	Mean	Std. Deviation
Assist one in coping with stresses of muscle gains in the gym	4.11	.837
Help improve the way I perform in the gymnasium	3.86	1.07
Be healthier	3.80	1.08
Help me to reduce cravings in order to decrease my body weight	3.85	.941
I feel pressured by my peers	3.65	1.05
Help me to reach my personal goals	3.60	1.11

Table 4. Sources of Information on Nutritional Supplements of the Gymnasium Users (n = 199).

Sources of Information on nutritional supplements	Yes	No	Rank %
Internet	181 (91)	18 (9)	1
Pharmacists	128 (64.3)	70 (35.2)	9
Books	112 (56.3)	87 (43.7)	11
Personal trainer	175 (87.9)	22 (11.1)	2
Newspapers	124 (62.3)	75 (37.7)	10
Magazines	139 (69.8)	59 (29.6)	6.5
Friends/Trainer partner	146 (73.4)	53 (26.6)	4.5
Journals	131 (65.8)	68 (34.2)	8
Representatives from nutritional companies	146 (73.4)	53 (26.6)	4.5
Information brochures	139 (69.8)	60 (30.2)	6.5
Physicians	155 (77.9)	44 (22.1)	3.5
Other	155 (77.9)	44 (22.1)	3.5

Data in the Table 4 show that majority of the respondents got information on NS from the internet followed by personal trainers, physicians, others, friends, and representatives from companies. The other sources of information on NS were brochures, magazines, journals newspapers, pharmacists, and books. The types of nutritional supplements consumed by gymnasium users were proteins (72%), sport drinks (69%), Fish oil (60%), caffeine (52%), herbal products (39%), glutamine (38%), carbohydrates (33%), vitamins (21.16%), and anti-oxidants (25%). Asked whether they read nutritional value benefits and side effects of supplements on the labels before use, 93 (46.7%) always read, 38 (19.1%) never, rarely 37 (18.6%) frequently 22 (11.1%) and sometimes 9 (4.5%). Asked whether the Gym instructor knew that as gym users they were using nutritional supplements 115 (57.78%) acknowledged that they knew while 84 (42.21%) opined that they did not know. When asked whether Gym instructors encourages use of nutritional supplements 44 (22.5%) responded yes while 155 (77.5%) said no. The attitudes of gymnasium users towards nutritional supplements are presented in Table 5.

Table 5: Attitudes of gymnasium users towards nutritional supplements (n = 199).

Attitudes	Mean	SD
I would never consider the use nutritional supplements to improve my performance	4.38	1.03
There are too many gym users using supplements to enhance their performance in Gymnasium	4.12	0.89
The use of performance enhancing supplements and nutritional supplements has increased in the last five years	4.05	1.11
Some think Gymnasium participants who want to reach their goal have to sometimes use performance enhancing supplements	4.02	1.23
Gymnasium should offer educational programmes for Gymnasium users on the use of supplements in Gymnasium	3.90	1.13
I do not think it is fair to use performance enhancing supplements	3.77	.92
I think it is always wrong to use nutritional supplements for gym purpose	2.67	1.43
Many of my friends think it is acceptable to use nutritional supplements	2.07	.94
The use of nutritional supplements by Gymnasium users has not been sufficiently reported in the media	2.05	1.7

The results in Table 5-show that-the gym goers had high means in the items; "*they would never consider the use of nutritional supplements*", "*there are too many gym users using supplements to enhance their* *performance in Gymnasium*", "*use nutritional supplements has increased in the last five years*", and the "*thinking Gymnasium that participants who want to reach their goal have to sometimes use performance enhancing supplements*". Therefore, it is apparent that the gym goers on one hand may want to keep off supplements, but on the other hand they are convinced that their peers are using them and there may be benefits associated with it. This effectively indicates that given an opportunity they will use nutritional supplements.

DISCUSSION

The study aimed at establishing the prevalence of NS among gym goers in Eldoret town, Kenya. The article sheds light why people go to the gym, use nutritional supplements, types of nutritional supplements used and attitudes towards nutritional supplements. The findings revealed most of the gymnasium users were male and had been a member of the gym for 2 or more years. The findings further indicated many participants went to the gym more than three times a week. These findings are supported by those of previous studies which have shown that men go to gym more than women (Jawadi et al., 2017; Morrison, et al., 2004; Muwonge et al.,2021; Ramic et al.,2020; Thakur & Brar ,2018).

The participants were going to the gym mainly for enjoyment and fun, toning their body, to be healthy and following medical advice. These findings have been reported in previous studies (Crossley, 2006; Dworkin, 2003; Eliason et al., 1997; Muwonge et al., 2021; Salami et al., 2017; Thakur & Brar, 2018). Indeed, Dworkin (2003) argued one of the primary objectives of gym goers is to achieve a physique that is perceived as aesthetic ideal in the contemporary society. Crossley (2006) alluded that some people go to gyms to relieve the pressure from daily life because they can redirect the focus (turn off consciousness) and learn how to manage pain/stress through exercise. Similarly, Eliason et al. (1997) had indicated that people go the gym for body building, health reasons, endurance/ cardiovascular, weight loss and performance enhancement.

The findings indicated that 110 (55.3%) of the gym goers used nutritional supplements while 89 (44.7%) did not use nutritional supplements. Other studies have reported similar results where over 50% of gym users consume dietary supplements (Lacerda, et al., 2015; Mazzini et al., 2021; Morrison et al., 2004; Thakur & Brar, 2018). For example, Locerda et al. (2015) found that supplements were used by 64.7% of the participants with 52.6% being males who exercised while Morrison et al. (2004) found that 84.7% took supplements. Mazzini et al., 2021 found that 85.4% of participants in their study used dietary supplements. This high prevalence of NS use is not comparable to other studies which have shown that 37.8% were NS users (Jawadi et al., 2017) and (Espinosa, et al., 2018; Ruano & Teixeira, 2020) where 43% used nutritional supplements. In a related study, Shariff et al. (2018) found that 49.5% men and 12.4% women reported that they use dietary supplements.

In this study, majority of the gym users consumed nutritional supplements to assist them gain desired muscle mass, to be healthier, and improve their performance (Table 3). These findings resonate with other studies which have reported that most gym users consume nutritional supplements to boost their performance (Jawadi et al., 2017; Molinero & Marquez, 2009; Muwonge et al.,2021; Salami et al.,2017) maintain good health, and supplement nutritional needs (Dickson & Mackay 2014; Jawadi et al., 2017; Salami et al.,2017; Thakur & Brar ,2018). Morrison et al. (2004) reported several reasons for gym goers to use nutritional supplements such as building muscles, to avoid illness in the future, to provide energy before, during, and after workout, boost power, and aid recovery. Similarly, Espinosa et al. (2018) opined that gym goers were using supplements in order to increase muscle mass, improve recovery and reduce body fat. The same reasons of consuming NS have been reported among the Dutch (Pajor et al., 2017) and Germans (Frey, et al., 2017) gym goers.

The findings show that most of the gym user's sourced information on nutritional supplements from multiple sources mainly internet, personal trainers and pharmacists (Table 4). These findings resonate with those of other studies which found out that online resources were the main source of nutritional supplements information (Attlee et al.,2018; Dickinson & MacKay, 2014; Phaladi, 2020; Maxwell, et al., 2017; Muwonge et al., 2021; Thakur & Brar, 2018). Indeed, Dickinson and MacKay 2014) reported that there is a lot of information encouraging consumers to purchase vitamins from the internet. The other sources of information on nutritional supplements were coaches, magazines, family/friends, personnel in vitamin/health food/supplement stores, books, and media. These sources have previously been reported as useful resources for nutritional supplements information (Alves & Lima, 2009; Attlee et al., 2018; Eliason et al., 1997; Jawadi et al., 2017; Muwonge et al., 2021; Ruano & Teixeira, 2020; Shariff et al., 2018). However, it is apparent that the gym users do not get information from credible sources such as nutritionist or dieticians.

The findings indicated that 58% of gym users review the label on nutritional supplement for information about the product. This postulates that the gym goers are aware of the nutritional value and benefits of the nutritional supplements. These findings are in congruence with findings from other studies (Creanor et al., 2017; Gabriel et al., 2012). For example, Creanor et al. (2017) found that 155 (41%) of the participants said they review the label on nutritional supplement products for information such as benefits and contraindications before purchasing. Similarly, Gabriel et al. (2012) found that 174 (48%) sometimes read the labels information, 149 (41%) always read the label and 39 (11%) read the labels information for a products nutrition value benefits and side effects.

Protein supplements were the mostly used type of nutritional supplement among the gymnasium users together with sport drinks and fish oils. The dominance use of proteins among gym goers has been reported in other studies (Bianco et al., 2011; Braun et al., 2009; Junejo et al., 2021; Muwonge et al., 2021; Ramic et al., 2020; Thakur & Brar, 2018). The other nutritional supplements of vitamins, minerals, and botanical products used by gym goers have been reported in previous (Barnes, et al., 2007; Dickinson et al., 2014; Espinoza et al., 2018; Foote et al., 2003; Jawadi, et al., 2017; O'Brien, et al., 2017; Ruano & Teixeira 2020). Indeed, Malik (2017) had reported that 14 different supplements were used by gym goers and it is possible that the gym goers could be using a combination of nutritional supplements.

The findings showed that most gym users had positive attitude towards nutritional supplements. The findings on positive attitudes towards nutritional supplements usage as perceived by the gymnasium users are supported in other studies (Kamber, et al., 2001; Sekulic et al., 2014) and this is not remote as a significant number of gym goers were using nutritional supplements believing that they can improve performance (Muwonge et al., 2021; Salami et al., 2017). Previous studies have stated that likely use of supplements among gym users who are persuaded that supplement is present in their sport (Muwonge et al., 2021; Sajber, et al., 2013; Sekulic, et al., 2014; Zenic, et al., 2013). Based on the "*false consensus effect*", then gym goers will use nutritional supplements because they believe others are using them.

CONCLUSIONS

Most gym goers use nutritional supplements and they were aware that nutritional supplements are prohibited. They sourced and obtained information on NS from the internet, personal trainers and physicians. . Gym users used the nutritional supplements for coping with gym stresses, improving performance and health.

They frequently read the labels before buying and using the nutritional supplement product. The gym goers went to the gym in order to be healthy, to condition their body, for enjoyment and fun and medical advice. The gym users perceived that using nutritional supplements was not bad at all as it enhances their performance.

Limitations of the study

The self-reported nature of the survey may have limited the reliability of the data. This is more apt as gym goers may not have been candid enough on their consumption of nutritional supplements. However, the gym goers were implored to be genuine in their responses and they were assured that their responses were for academic uses only. The other limitation is that the study conducted among gym goers in Eldoret Town, Kenya which does not allow for generalizations to all the gym goers in Kenya. But the findings could be treated as an indicator on the use of DS among gym goers and spur similar studies in other towns in Kenya.

Recommendations

The gym goers need education on consumptions of nutritional supplements. The concerned gyms owners and management should explore all possible means of addressing the problem, which may include improving access to nutritional supplements information and developing structures and regulations related to nutritional supplements. Other studies should be carried out in cities like Nairobi and Mombasa to find out whether prevalence of NS varies from city to city. The effects of nutritional supplements among its users should be carried out. Also, other studies should emphasis on the policies and regulations related to the consumption of nutritional supplements.

AUTHOR CONTRIBUTIONS

Conceptualization: Elijah G. Rintaugu & Henry Mukolwe. Methodology: Henry Mukolwe & Francis M. Mwangi. Data collection and analysis: Francis M. Mwangi. Initial writing: Henry Mukolwe & Jonathan Rotich. Review and Editing: Elijah G. Rintaugu & Jonathan Rotich.

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SCIENTIFIC JOURNAL OF SPORT AND PERFORMANCE

ORIGINAL ARTICLE

The effect of physical activity on the quality of life of emergency room nurses working in public hospitals

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ABSTRACT

The aim of this study is to investigate the effect of physical activity on the quality of life of emergency room nurses working in public hospitals. The sample for the preliminary research consisted of 476 nurses, working in emergency rooms in the 3rd, 4th and 5th Health Regions of Greece. The participants' ages ranged from 22 to 60 years (age 42.49 ± 9.5 years). The latter completed questionnaires where the quality of life and physical activity were assessed. The questionnaire SF12 was used – a questionnaire developed as a shorter alternative solution to the questionnaire SF36 (Ware & Sherbourne 1992). Furthermore, for the assessment of physical activity, the International Physical Activity Questionnaire (short version) was used (Craig, et. al., 2003). The results of statistical analysis showed that nurses' quality of life level was low, and the majority of nurses displayed a low level of physical activity. Also, according to the post-hoc Scheffe test, physical activity is directly correlated to the quality of life, because it positively affects physical and mental health indicators - $F(2,473)$, $p < .05$. We conclude that physical activity helps to improve the quality of life parameters, improving physical and mental health indicators.

Keywords: Physical activity psychology, Sport Medicine, Physical health, Mental health, Sports health.

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INTRODUCTION

As defined by the World Health Organisation (WHO), physical activity is any bodily movement produced by skeletal muscles that requires energy expenditure higher than that of resting energy expenditure, i.e., any bodily movement caused by muscle contraction that requires energy expenditure (WHO 2004). Consequently, physical activity apart from exercising and sports, may also be doing housework. Sports is defined as a strictly structured physical activity, under rigorous rules, high levels of competition and specialisation, whose basic aim is to maximise athletic performance. On the other hand, exercising is defined as each systematic bodily movement or participation in physical activities, that is time-limited, less competitive and where, mostly, the body's major muscle groups are involved (Berger et al.,2007).

WHO guidelines recommend the following for individuals in the age range 18-64: a) at least 150–300 minutes of moderate-intensity aerobic physical activity per week or 75 minutes of vigorous-intensity aerobic physical activity weekly or an equivalent in time combination of moderate and vigorous-intensity activity (e.g., 75 minutes of moderate + 30 minutes of high-intensity activity). b) muscle-strengthening exercises with an emphasis on major muscle groups, that must be undertaken at least twice a week. (WHO,2004).

For additional health benefits, individuals should increase moderate-intensity aerobic physical activity from 150 to 300 minutes weekly or commit themselves to more than 150 minutes of vigorous-intensity aerobic physical activity or an equivalent in time combination of moderate to high-intensity activity. Each aerobic physical activity session should be at least 10 minutes long. (WHO,2004).

Exercising systematically over a long period of time, strengthens body muscles, diminishes excess fat, defines muscles and results in a graceful and attractive physique. Strengthening the muscles has a very practical result: it enables individuals to effortlessly carry out daily bodily activities whist dealing with any additional problems with ease. Individuals become productive without getting overly tired. Their self-esteem is boosted as is their satisfaction, feelings that are so important for our mental health (Hornquist, 1982).

The quality of life was originally associated with the concept of the standard of living as it included concepts related to the consumer society, as owning electrical appliances, cars and a residence, i.e., purely material goods. (Fallowfield, 1990). Later, the term "*quality of life*" was expanded to include the rate of satisfaction of needs, as regards the physical, mental, social, material and structural areas of life.(Hornquist, 1982).

The concept of health-related quality of life has been at the forefront of scientific research in recent years. It expresses the subjective feeling of fulfilment and safety as well as the feelings of satisfaction and pleasure that an individual experiences by participating in all activities of everyday life (Ventegodt, 1995).

As regards the first factor, i.e. Physical health, it has been established that the contribution of physical activity to the quality of life, is that it reduces the risks for obesity, coronary artery disease, type II diabetes and breast and colon cancer(Williamson et al., 2004). As to the second factor, i.e. mental health, exercise brings about pleasure associated with well-being and life satisfaction. The release of "*endogenous*" opioid substances created inside the body during physical activity, as β-endorphin and β-lipotropin, prompt euphoria either during or after exercising(Clarke and Haworth, 1994).

A substantial proportion of emergency room nurses display burnout symptoms as a result of low quality of life levels. Also, many researchers maintain that the percentage of burnout in emergency room nurses is higher than that of nurses working in other hospital departments, such as intensive care units, surgery departments etc.(Adriaenssens et al., 2015; Robin and Leslie, 2006).

The aim of the study

The aim of this study is to investigate the effect of physical activity on the quality of life of emergency room nurses working in public hospitals.

Through the findings of this research, this research hopes to provide public and private sector health care units with guidelines for developing and materialising motor activation models which will potentially contribute to increasing the active life span of emergency room nurses in Greek hospitals. It will also try to shed light on some of the recent main research interest topics in the field of Physical Activity and especially in the field of exercise and mental well-being.

Specifically, the research has two sub-objectives. The first is to record and evaluate the levels of physical activity and quality of life of workers, and the second is to track the relation between physical activity as a health behaviour and the quality of life of emergency room nurses.

MATERIAL AND METHODOLOGY

Participants

The research sample consisted of 476 nurses, both male and female, working in public hospital emergency rooms in the 3rd, 4th and 5th Health Regions of Greece. In total 476questionnaires were filled out and used for statistical analysis. The sample consisted of 355women and 121 men, with an average age of about 43 years (mean = 42.49, SD = 9.5). To facilitate date analysis, the participants were grouped in four categories based on data distribution. The first category consisted of nurses in the 22-32 age group, the second in the 33-43 age group, the third in the 44-54 age group and the fourth in the age group 55 and over. A prerequisite to participating in the research, is that the nurses have been employed for at least one year in the specific department and that they are permanent civil servants serving in the 3rd, 4th and 5th Health Regions.

Furthermore, 50.5% were married, followed by singles at 36.3%. Divorcees were at 13.2% whilst 58% of the total sample indicated that they were parents. As regards the educational level of the employees, most, 51%, were higher technological school graduates (N = 245), 39% (N = 185) were secondary school graduates, whilst the percentage of university graduates was the lowest at 10% (N = 46). The percentage of participants holding postgraduate degrees (both university graduates and higher technological school graduates) was only 15.5% (N = 74).

Measures

For the assessment of physical activity, the International Physical Activity Questionnaire (IPAQ, short version) (recall period one week) was used (Craig, et. al., 2003). Specifically, the said questionnaire consists of 7 questions collecting information on the time consumed daily in vigorous, moderate and walking activities as well as the time consumed sitting at rest over a seven-day period. The daily physical activity was assessed in MET (MET is a unit that represents the energy spent sitting at rest. 1 MET = 3.5 nil 02 /kg body weight/minute, which is the oxygen consumed sitting at rest), as per the official protocol of IPAQ Being. Three classification categories of physical activity were built based on the values: a)low physical activity, b)moderate physical activity, c) high physical activity.

For the assessment of the quality of life, the questionnaire SF12 was used, a questionnaire developed as a shorter alternative version of the questionnaire SF36 used for large-scale studies, and science the results that interest us, are those of physical and mental health, theSF12 was more appropriate for our needs, as opposed to the characteristic SF36 that consists of eight scaled scores (Ware & Sherbourne 1992).

The aim of the questionnaire is to measure the eight sections of the quality of life that are associated with health. These eight sections are as follows: Physical functioning (PF), physical role functioning (RP), bodily pain (BP), general health perceptions (GH), vitality (VT), social role functioning (SF), emotional role functioning (RE) and emotional well-being or mental health (MH) (Ware 1992).

The scaled scores range from 0-100. When the result obtained is <50, what it indicates is that the health of the patient is below the mean (Ware & Sherbourne 1992). Each assessment scale corresponds to a specific number of close ended questions with a distinct set of pre-defined responses. The range of options in responses ranges from 2–5 gradations (e.g. there are questions where the response either has two options, "*Yes*" or "*No*", or three options: (a) "*Yes, it limits me a lot*", (b)"*Yes it limits me a little*", (c)"*Not it does not limit me at all*", or five options: (a)"*Not at all*", (b)"*Slightly*", (c)"*Moderately*", (d)"*A good bit of the time*", (e) "*Very much*"(Ware and Sherbourne 1992).

The scoring of each section can be converted into a percent, where the value 0 represents the lowest possible score and the value 100 (perfect health) the highest possible score. The scores between these two extreme values depict the ratio of the final total score of the scale measured. The higher thus the participant's score, the better the quality of his/her life (Ware et al., 1998). The eight sections are summarised into two total results, the first relating to the overall physical health and the second to the overall mental health, and as measurable indicators, and for the sake of brevity, they are namedPCS-36 and MCS- 36 (Ware and Stewart,1996; Ware et al.,1998).

Procedure

The participants were informed that all questionnaire answers would be confidential. The questionnaires were completed from January 2022 to April 2022. Each nurse completed three questionnaires, one on physical activity, one on burnout and one on their demographics, during their work, in the presence of the researcher. Firstly, permission was requested from the Board and Scientific Council of each hospital for conducting the research, as well as from the Ethics Committee of the Democritus University of Thrace. Permission from the latter was granted on 16/12/2021 under permission no. 25075/168.Thereafter, the head and director of the department was informed about the goals and the content of the research. After the briefing, participants were advised that a)their participation was voluntary, b)the questionnaires were anonymous, c)absolute confidentiality would be maintained and d)the results would be used solely for scientific purposes.

Analysis

Data analysis was run using the statistical package SPSS 17.0 for Windows. The internal consistency of tests and measures was assessed by using Cronbach's alpha reliability coefficient. Mean and standard deviation and/or medians were used for describing the quantitative variables. Absolute values (N) and relative frequencies (%) were used to describe the qualitative variables. Also, in order to examine whether there were differences in factors between quality of life (dependent variable) and the level of physical activity (independent variable) a two-way MANOVA was performed (multivariate analysis of variance), and to test differences between the groups, Scheffe's post hoc test was carried out. The significance level was set to $p < .05$.

RESULTS

Cronbach's alpha reliability coefficient

The internal consistency of the questionnaire's factors of quality of life, was measured using Cronbach's alpha coefficient**.** The results showed that most variables had a high degree of internal consistency, and especially so as regards the variable "*physical role functioning*" (RP = 0.83) (Table 1).

Table 1. Results of reliability testing, survey instrument SF-12.

Factor	Cronbach coefficient α
Physical functioning (PF)	0.78
Physical role functioning (RP)	0.83
Bodily pain (BP)	0.81
General health (GH)	0.81
Vitality (VT)	0.81
Social role functioning (SF)	0.81
Emotional role functioning (RE)	0.66
Emotional well-being or mental health (MH)	0.72

Level of physical activity

The level of physical activity of the research participants was measured using the International Physical Activity Questionnaire (IPAQ, short version). Table 2 depicts the level of the participants' physical activity, which was divided into three categories (1 = low activity, 2 = moderate activity and 3 = high activity). Analysing the levels of physical activity, it was shown that 44.5% of nurses displayed a low level of physical activity, 33.4% displayed a moderate level of physical activity and 22.1% displayed a high one.

Table 2. Participants' level of physical activity.

Physical activity level	N	%
Low activity	212	44.5%
Moderate activity	159	33.4%
High activity	105	22.1%
Total	476	100%

Level of quality of life

The participants' quality of life (QOL) was measured using the scale SF12 and the values found by category are described in the table below (Table 3). The results of the individual dimensions showed low mean values that ranged between 42.55 and up to 59.30. The lowest mean value was found to be that of "*physical role functioning*" (Mean = 42.55, Standard deviation = 45.783) whilst the highest was that of "*physical functioning*" (Mean = 59.30, Standard deviation = 32.791). The common feature of these results is the high standard deviation which corresponds to at least to one third of the mean. The average coefficient of variation was equal to 0.595, indicating that on average, the standard deviation was equal to 60% of the mean value.

The effect of physical activity on the quality of life

To analyse the variance of the quality-of-life factors with the factor of physical activity the Multivariate Analysis of Variance (MANOVA) technique was performed. The purpose of this research was to examine the research hypothesis regarding the parallel effect of the level of physical activity on quality of life dimensions.

This particular analysis is used to study the effect of two or more categorical variables, which in this case will be referred to as factors, on a multitude of quantitative variables. Categorical variables are to be understood as independent variables and quantitative variables are to be understood as dependent ones. The categorical-independent variable in this specific study is physical activity in three levels (1 = low physical activity, 2 = moderate physical activity and 3 = high physical activity), whilst the dependent variables are the scales (variables) of the questionnaires on quality of life.

Table 3. Measures of location and dispersion of the dimensions quality of life.

Factor	**Mean ± SD**	**CV**
Physical functioning (PF)	59.30 ± 32.79	0.55
Physical role functioning (RP)	42.55 ± 45.78	1.07
Bodily pain (BP)	55.81 ± 27.50	0.49
General health	53.20 ± 24.79	0.46
Vitality (VT)	51.18 ± 24.68	0.48
Social role functioning (SF)	57.65 ± 27.67	0.48
Emotional role functioning (RE)	42.55 ± 45.78	1.07
Emotional health or mental well-being (MH)	56.79 ± 20.16	0.35
Physical component summary (PCS)	52.72 ± 26.92	0.51
Mental health component summary (MCS)	52.04 ± 23.67	0.45

Table 4. Effect of physical activity on quality of life.

Factor	**Activity**	**N**	**Mean ± SD**	**F (2,473)**	***p***
Physical functioning	Low	212	44.46 ± 31.85	55.89	.000
	Moderate	159	65.41 ± 29.06		
	High	105	80.00 ± 25.09		
Physical role functioning	Low	212	80.00 ± 25.09	51.49	.000
	Moderate	159	45.91 ± 45.69		
	High	105	74.29 ± 40.49		
Bodily pain	Low	212	44.67 ± 25.53	41.58	.000
	Moderate	159	60.79 ± 23.83		
	High	105	70.76 ± 27.42		
General Health	Low	212	45.52 ± 24.53	25.64	.000
	Moderate	159	55.50 ± 22.79		
	High	105	65.24 ± 22.86		
Vitality	Low	212	40.75 ± 24.30	57.94	.000
	Moderate	159	53.33 ± 20.21		
	High	105	68.95 ± 20.37		
Social role functioning	Low	212	47.17 ± 25.41	40.52	.000
	Moderate	159	60.75 ± 26.13		
	High	105	74.10 ± 25.25		
Emotional role functioning	Low	212	24.32 ± 38.77	51.49	.000
	Moderate	159	45.91 ± 45.69		
	High	105	74.29 ± 40.49		
Emotional health or mental well-being	Low	212	48.92 ± 19.42	43.53	.000
	Moderate	159	59.12 ± 18.77		
	High	105	59.12 ± 18.77		
Physical component summary (PCS)	Low	212	39.74 ± 24.19	71.42	.000
	Moderate	159	56.90 ± 23.71		
	High	105	72.57 ± 22.39		

	Low	212	40.29 ± 20.34		
Mental health component summary MCS)	Moderate	159	54.78 ± 20.71	85.54	.000
	High	105	71.62 ± 19.70		

The results of this testing are presented in Table 4, and it was shown, that in all cases, when testing the variables independently, physical activity was a statistically significant factor as regards differences in means. In fact, the significance in all cases was quite high ($p < .001$). Also, according to the post-hoc Scheffe test, physical activity is directly correlated to the quality of life, because it positively affects physical and mental health indicators - $F(2,473)$, $p < .05$. It was also found that in all quality of life variables, there was a positive effect on the level of physical activity and an increase of the quality of life in a stable linear pattern.

Based on the above, we observe that the level of physical activity effects the factors of quality of life. Nurses with a low level of physical activity had higher scores on the variables of quality of life, in comparison to their co-workers who had a moderate to high level of physical activity.

DISCUSSION

What we tried to record in this research, was the degree of quality of life that emergency room nurses, both male and female, experience, and the benefits that a motor activation model provides.

As shown by data analysis, physical activity levels of emergency room nurses are not satisfactory – 44.5% of the sample displayed low physical activity and only 22.1% displayed a high one. Generally, the percentage of the Greeks participating in a physical activity is lower than that of the Europeans as a whole, even though an increase has been noted in recent years (Tzormpatzakis and Sleap, 2007). It is characteristic, however, that the Greeks report that they participate in a vigorous physical activity more days than other Europeans (Rütten et al., 2004).

However, according to a study conducted in 22 public Brazilian hospitals, Burdick et al. (2014) concluded that nurses living in other countries also lead an unhealthy lifestyle. This was determined while trying to explore the overall knowledge that nurses possessed on physical activity issues and health recommendations. The results showed that the majority of nurses required additional information on starting to engage in exercise programmes. Furthermore, traditional obstacles mentioned in international bibliography that hinder engagement in exercising were also presented in the study in question. The main factors that act as deterrents to engaging in physical exercise are lack of time, of education and training as well as lack of institutional support (Burdick et al., 2014).

A current research conducted in the United Kingdom by Blake et al. (2019) reached the same conclusions. 1.452 hospital workers including many nurses working at the National Health System (NHS) participated in the research. 45% of nurses did not meet the guidelines of the recent WHO protocols that recommended 30 minutes of moderate daily physical activity. Reasons mentioned for not taking part in physical activity programmes, were fatigue, non-existent free time as well as incentives. Also other factors causing them to refrain from exercising were lack of time, a feeling of tiredness, lack of incentive, working shifts and animosity at the workplace.

Withal, the aim of this study is to determine the level of the quality of life of nurses. The results showed that all factors of the questionnaire displayed low means, the values ranging from 42,55 and up to 59,30. We thereby observe that nurses' overall quality of life is low.

According to Brooks and Anderson (2005), the quality of life of nurses is defined as being "*the extent to which nurses are able to satisfy important personal needs through their experiences in their work organisation while achieving the organisation's goals.*" Consequently, the concept of work satisfaction does not just imply securing a job and a salary, but also securing a working environment where the individual feels accepted and appreciated.

The results of the said research coincide by the those of the research carried out by Schutz and Shattell (2020), who, during the pandemic, evaluated the quality of life of emergency room nurses as well as that of nurses working in departments that cared for SARS-COV-2 patients. The results showed that workers had a low quality of life due to social isolation that they imposed on themselves, in fear of transmitting an infectious disease to their acquaintances and loved ones.

In addition, a number of earlier researches undertaken, blame a variety of factors for the negative effects on nurses' physical and mental health. Some of these factors include round-the-clock shifts, a rapid working pace, the intensity of the work plus the uncontrollable flow of patients especially in emergency rooms. All of the above impact nurses' physical health since it has been proven that they have a 77% higher chance of carcinogenesis. Moreover, their mental health is also affected since problems and conflicts in both their family and social life were also reported.

In regard to the research hypothesis as to the degree to which the indicators of the quality of life differ when correlated to the level of physical activity, analysing the results, it was found that nurses with a high and moderate physical activity level displayed higher scores on the indicator of the quality of life compared to that of nurses with low activity levels. The hypothesis that emergency room nurses' quality of life differs depending on their level of physical activity, is thus confirmed.

The engagement in interests and activities as brisk walking, dancing, jogging and cycling or other sport activities, help to reduce emotional tension and work pressure improving nurses' quality of life indicators (Bährer,2018). Matsugaki's (2017), research conducted in Japan yielded similar results. What was assessed was the effectiveness of supervised exercise among nurses working round-the-clock shifts with the aim of enhancing their quality of life. The average scores of the questionnaire on the quality of life increased significantly, meaning that a physical activity programme can amount to a useful tool for the work performance of emergency room nurses. A healthy diet and exercising accompanied by the necessary rest, can strengthen the body and prevent the occurrence and the development of the phenomenon of work fatigue which undoubtably affects the quality of life. These measures can, each individually, and each in its own way, significantly reduce the levels of stress development, and thus obviate the risk of leading nurses to chronic stress and burnout (Peterson et al., 2008; Bährer,2018).

CONCLUSION

Improving the quality of life of emergency room nurses, will bring about a number of benefits to both employees and health care providers themselves. The quality of life of nurses which is greatly influenced by the quality of their work life, should not take a back seat as it often has an impact on the quality of services provided.

Hospital administrations should promote motor activation programmes for personnel which can take place on site after working hours, under the guidance of a gym teacher. However, engaging solely in physical activities is not a panacea for the improvement of nurses' quality of life - medical equipment, working hours, psychological support, training and adequate staffing of hospitals in nursing staff are some strategies to enhance and protect the overall health of workers (WHO, 2021).

Limitations

The participants of this survey were practising emergency room nurses working in the 3rd, 4th and 5th Health Regions of Greece. The sample size was adequate for generalisation of the results as regards the population under study. However, generalising the results of the nurses as a whole, regardless of their level of education (University graduates, Higher technological school graduates, secondary school graduates) should be avoided. Moreover, even though the questionnaires were anonymous, it is impossible to verify the honesty of the answers of research participants as it is impossible to verify the degree to which the questions of the research sample were understood. Therefore, future studies with a larger sample size are needed to confirm the results of this study. The Community Nurse in collaboration with the physical education teacher, can play a catalytic role in promoting physical activity in the community, and hence promote the health and well-being of people.

AUTHOR CONTRIBUTIONS

Conceptualization: I. Leridis, O. Matsouka, E. Bebetsos and G. Kosta. Data curation: I. Leridis. Formal analysis: I. Leridis and O. Matsouka. Investigation: I. Leridis. Methodology: I. Leridis and O. Matsouka. Project administration: O. Matsouka, E. Bebetsos and G. Kosta. Resources: I. Leridis. Supervision: O. Matsouka, E. Bebetsos and G. Kosta. Validation: I. Leridis. Visualization: I. Leridis. Writing –original draft: I. Leridis. Writing–review & editing: I. Leridis and O. Matsouka.

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ORIGINAL ARTICLE

Study on the performative effects of cause-based vs effect-based teaching in adolescent athletes: Evaluation of lower limb explosive strength

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ABSTRACT

Purpose Understanding how humans generate movement is a fundamental goal due to its implications. The authors based their study on the methodological applications in sports of the Synchrony Theory. (DeBernardi, 2008; in press Fogliata et al., 2023) In paradigm, the perceived movement corresponds to an Effect-Movement. The motor teaching of a gesture based on the Effect can be defined as Effect-based Teaching (EbT). Motor teaching based on the visible movement of a gesture can be defined as Effect-based Teaching (EbT). While teaching based on what caused the gesture can be called Cause-based Teaching (CbT). Methods. authors aimed to evaluate the possible differences in explosive lower limb strength in the Sargent Test among adolescents instructed through these three models of demands. Results. All athletes were subjected to all three types of tests. The data showed that teaching based on Causes allows improvement of the entire group and two-thirds of the participants significantly compared to Effects-based teaching. Technical teaching also had a better outcome than Effects-based teaching, but only for a third of the sample. Conclusion. Teaching based on Causes seems to be an excellent tool for increasing performance, simple to apply and effective, allowing for instant improvement.
Keywords: Physical education, Cause-based teaching (CbT), Effect-based teaching (EbT), Internal attention, Sargent Jump Test, Performance analysis of sport.

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INTRODUCTION

Scientific studies have examined the effects of attention on motor performance and learning, stating that when athletes focus on bodily sensation rather than on an external goal, they improve their performance and technical learning (Wulf and Shea, 2002). Results suggest that attention to muscle action or movement information is important for motor control and motor learning, highlighting the importance for sports coaches to understand how to guide the athlete's attention, especially during the learning phase (Langer and Moldovean, 2000; Schmidt, 1991).

Based on the Synchrony movement model and the results obtained in a previous study on running (Debernardi, 2008; Fogliata et al., 2023), the authors suggest that it is possible to distinguish between primary muscles that give rise to the action (Causanti) from those used in the resulting movement itself (Effettori). Ivanenko and colleagues in 2004 focused on how the origin of movement, in that case of gait, should be considered based on propulsion (cause) rather than the heel strike event or stride length (effect) (Ivanenko et al., 2002). If this were the case, the authors presume the possibility that there may be different responses not only if the athlete's attention is internal versus external but also if it is placed on the Causes rather than on the effects of the action to be generated.

The authors thus created a paradigm for evaluating performance in adolescents by providing them with instructions based on the causes, rather than on the effects or technical explanation. The evaluation study chose to assess female athletes, as they are less influenced by muscular strength (Malina and Bouchard, 1991; Beunen and Malina, 1996; Sherar et al., 2007). The sample was in the pubertal age group, and the differences in muscular strength between the sexes decrease with increasing age and female sexual maturity, so it is assumed that in this growth phase, the performance recording is as distinct as possible from strength recording (De Ste Croix et al., 2003; Faigembaum et al., 1996).

Moreover, the vertical jump test was chosen. This test is used to measure the lower limb muscle power and explosiveness of athletes. It is a relevant test in various sports disciplines such as basketball, volleyball, soccer, and track and field. The most common vertical jump test involves jumping from a standing position and measuring the distance between the starting point and the highest point reached during the jump, using the so-called Reach parameters (Bosco et al., 1983; Sayers et al., 1999; Markovic et al., 2004).

Among vertical jump tests, the most used is the Sargent variant, used to evaluate the lower limb explosiveness and muscle power of athletes and as an indicator of their ability to generate force quickly. It is also used as an assessment tool for sports performance and as a means of monitoring athletes' progress over time (Young and James, 2009; Bailey and Maillardet, 2010; Trecroci et al., 2015). Furthermore, this test has often been used to evaluate explosive capabilities in adolescent athletes. In his 2018 review, Schwesig evaluated gender and age differences in vertical jump performance using this test. There are studies that specifically suggest that females are less influenced by strength in vertical jump performance during puberty. (Moran et al., 2006; Sayers et al., 1999).

In conclusion, we can say that the vertical jump test is an important indicator of lower limb muscle power and athlete explosiveness. In pubescent females, this value is less influenced by muscle strength, allowing for greater observation and study of kinetics (Lloyd et al., 2014). Finding differences in the same test for the same athlete based on teaching methods (cause vs. effect) may indicate an actual need to differentiate internal focus on a specific muscle area.

METHODS

We chose to use a test for evaluating vertical jump, the Sargent Jump Test (SJT), also known as the Vertical Jump Test or Standing Vertical Jump Test (Sargent, 1921). SJT is used to evaluate the power and explosive strength of the lower limbs expressed in a jumping task. The test was performed by each athlete jumping vertically in front of a graded wall, without a running start, and touching the highest possible point on the wall with their fingertips. The measure of the jump was taken as the distance between the lowest fingertip touch and the floor. The result of the test is expressed in centimetres and represents the maximum height reached by the vertical jump. The formula used to calculate the test score is: Sargent Jump Test = Average of jumps - Reach. The average of jumps represents the average of five consecutive but separate jumps allowing for adequate repositioning performed by the subject. The reach represents the distance between the floor and the individual's fingertips with their arm fully extended in an upright position. (Ibidem)

Each athlete-subject performed SJT for three different sessions. Each session was distinguished by the type of executive teaching proposed. Each session was preceded by a heart rate check that should not have been more than 5 bpm compared to the baseline. All participants had never undergone this test before. The test sessions, which we will call S1-S2-S3, were randomized. To avoid executive learning, the sessions were carried out at the necessary time interval to allow the athlete-subject the necessary recovery and learning of the different executive request. No athlete had different teachings, and no motivation was provided during execution. All subjects performed tests S1, S2, and S3 on linoleum flooring, with appropriate footwear, and at the same time of day, in the luteal phase. Some studies have shown a positive correlation between the follicular phase and muscle performance (Lebrun et al., 1995; Sung et al., 2014). All executive teachings were given before the start of the test sessions. The present experimenters were always two.

In the S1 jumping session, the subject was asked to "*jump as high as possible, go as high as possible, reach the highest point of the wall with their hands.*" S1 can, therefore, be attributed to the test session in which the teaching was for effects, the athlete's attention was placed on the effect of the thrust, going up, and not on the cause. This instruction was given to focus attention on the effect of the pushes, i.e., jumping upwards, not on the cause, the push downwards.

In the S2 jumping session, the subject was asked to "*push down the floor, push the floor as hard as possible, imagine sinking it.*" S2 can, therefore, be attributed to the test session in which the teaching was for causes, the athlete's attention was placed on the cause of the jump, i.e., the push of the lower limbs downwards. This indication was used to focus attention on the real cause of the jump, which is the downward push of the lower limbs.

In the S3 jumping session, the subject was asked to "*remember the correct jumping technique, concentrate on the jumping technique, jump as if they were performing a technical exercise.*" S3 can, therefore, be attributed to the test session in which the teaching was technical, the athlete's attention was focused on the vertical jump technique.

Sample

All the tested subjects were Caucasian females with ages ranging from 13 to 17 years.

All subjects were selected from a sample of trained female athletes with the same experience in vertical jump technique. Furthermore, they were selected based on their sports training ability, excluding those who did not show the ability to understand the commands in pre-test tasks, ensuring the ability to understand and apply the requests made by the experimenters.

All subjects underwent S1, S2, and S3 tests after checking their baseline heart rate and randomizing the test sessions.

A total of 70 subjects with a mean age of 15.2 years were tested. All athletes were healthy, and none were in functional recovery. All athletes were found to be symmetric in lower limb morphology control tests.

Data analysis

The S1 test (taught for EFFECTS) shows a normal distribution of the results (in cm) of the high jump measurement. The measurement of the jump obtained in the three tests was compared, verifying both the mean and the distribution of any observed variations. The results were also checked through a significance test of the data using logistic regression analysis.

Figure 1. Test S1. Distribution by results.

RESULTS

The mean measurement of the jumps obtained in the S1 test is 38.1 cm. In the S2 (taught for CAUSES) and S3 (taught for TECHNICAL) tests, an improvement in the mean of the jump measurement is observed:

- S2 test (taught for CAUSES): mean jump measurement = 39.0 cm, an average increase of +0.9 cm (+2.6%) compared to the mean measurement recorded in the S1 test.
- S3 test (taught for TECHNICAL): mean jump measurement = 38.5 cm, an average increase of +0.4 cm (+1.1%) compared to the mean measurement recorded in the S1 test.

The most interesting results come from reading the observation of the distribution of the improvements obtained within our reference sample. For each athlete, the variation (improvement or deterioration) of the jump measurement in the S2 and S3 tests was calculated compared to what was recorded with the S1 test.

In the jumps performed in the S2 test (taught for CAUSES), it is observed that:

- No athlete showed a deterioration in the jump measurement reached.
- 23.2% of the athletes did not improve their jump measurement.

- 62.3% of the athletes improved their jump measurement by 1 cm, equivalent to a +2.6% increase compared to the results obtained in the S1 test.
- 14.5% of the athletes improved their jump measurement by 2 cm or more, equivalent to a +6.4% increase compared to the results obtained in the S1 test.

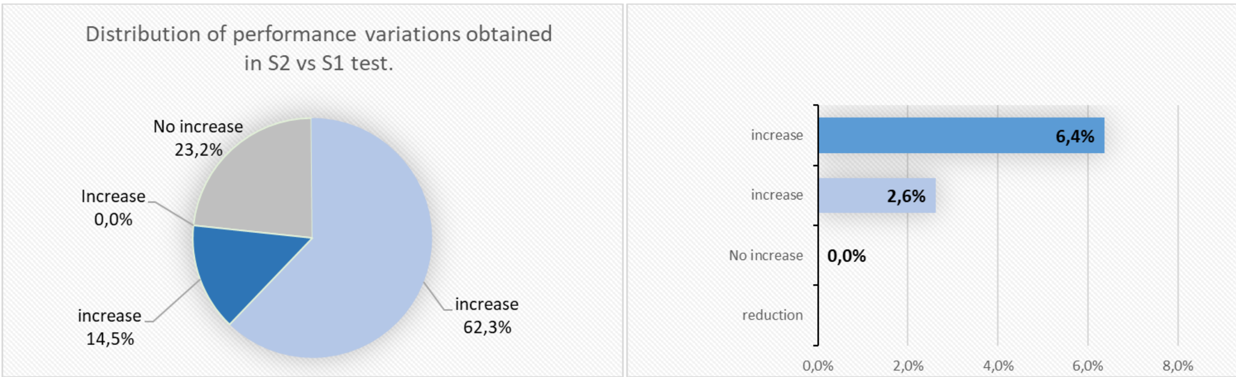

Figure 2. Distribution of performance variations obtained in S2 vs. S1 test.

In the jumps performed in the S3 test (taught for TECHNICAL), it is observed that:

- 17.4% of the athletes deteriorated their jump measurement by 1.1 cm, equivalent to a -2.8% decrease compared to the results obtained in the S1 test.
- 47.8% of the athletes did not improve their jump measurement.
- 18.8% of the athletes improved their jump measurement by 1 cm, equivalent to a +2.6% increase compared to the results obtained in the S1 test.
- 15.9% of the athletes improved their jump measurement by 2 cm or more, equivalent to a +7.4% increase compared to the results obtained in the S1 test.

The significance of the variation in jump height measured in Tests S2 and S3 compared to Test S1 was also verified through a logistic regression analysis, which showed a moderate significance of .06.

Figure 3. Distribution of performance variations obtained in S2 vs. S1 test.

CONCLUSION

In this study (Lee, 2017), several bibliographic sources were used to support the conclusions. Specifically, the work of Wulf (2013) on the effects of attentional focus on motor learning was considered, as well as the systematic review by Schoenfeld and Contreras (2016) on the effect of attentional focus on muscle strength and hypertrophy. The results of this study indeed showed that teaching based on athletes' attentional focus on their own body is an important performance variable. In fact the technical teaching of correct execution of the kinetic gesture (Technical Teaching, test S3) led to visible improvements in 34.7% of the sample, a deterioration in performance in 17.4% of the athletes, and no difference in results in almost half of the cases (47.8%).

The motor teaching based on the description of non-visible muscle contractions that initiate the visible movement (Effect-Movement) and that are the cause (Cause-Based Teaching, test S2) led to visible improvements in 77.8% of the observed sample, and in no case was a deterioration in performance observed.

It seems that the Cause-Based Teaching is more immediately understandable and actionable by athletes, leading to improvements in about 3 out of 4 athletes (77.8% showed an improvement in performance). Moreover, this tool does not have any contraindications or create complications in the motor mechanics that could translate into a deterioration in performance. In fact, in no case was a deterioration in performance observed.

Cause-Based Teaching seems to be an excellent tool for increasing performance, of simple application and very effective, allowing for immediate improvement.

Another interesting consideration that emerges from this study is the need to personalize teaching and training approaches to adapt to the specific needs of athletes. As highlighted by the results, there are athletes who respond better to a teaching approach based on correct execution of the kinetic gesture, while others benefit more from teaching focused on the cause of muscle contractions.

This means that coaches and teachers must carefully evaluate the individual needs of athletes and adapt their teaching approach accordingly. This customization can be facilitated using tools such as movement execution technique evaluation and evaluation of athletes' attentional focus during learning.

Furthermore, this study emphasizes the importance of ongoing scientific research in the field of motor learning to improve athletes' performance and develop new teaching and training approaches. Analysis of research results can help coaches and teachers better understand how athletes learn and how their teaching and training approaches can be improved.

An interesting suggestion for future research could be to further investigate the possible differences in motor learning between athletes, particularly young athletes, in relation to the use of different teaching approaches.

In particular, it would be interesting to evaluate the effectiveness of an approach based solely on technical teaching compared to an approach based on both technical teaching and the focus on the cause of muscle contractions in training young female athletes.

A possible method to test such differences could be a two-group experimental design, where one group of athletes would be trained using only a technical teaching model, while the other group would be trained using both technical teaching and teaching based on the focus on the cause of muscle contractions.

Moreover, it would be interesting to monitor the long-term effects of training, for example through the analysis of data on the athletes' performance in official competitions.

This research could provide valuable information for coaches and teachers on the most effective teaching methods for young athletes, which could be used to develop personalized and targeted training programs.

AUTHOR CONTRIBUTIONS

A. Fogliata: Author of the methodology and creator of the paradigm, coordinator of the field data collection, wrote the article except for the part related to the statistical analysis and results. R. Borghini: Author who conducted the statistical analyses and wrote the statistical results. Shared the observations for the drafting of the conclusions. A. Ambretti: Author of methodology and conclusion she is scientific coordinator of work.

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