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ORIGINAL ARTICLE

Relationship between dry-land upper-limb power and underwater stroke power using medicine ball overhead slam as a predictor of swimming speed by upper limbs only

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ABSTRACT

The relationship between power output underwater and on land was investigated by evaluation of underwater power output by the back and upper limbs. Thirteen male competitive swimmers performed the one underwater arm stroke (OUAS) trial, medicine ball overhead slam (MBOS) trial, and lat pull-down test as a predictor of back and upper-limb strength and power underwater and on land. The maximum horizontal velocity of the greater trochanter in OUAS correlated with all vertical velocities of the MB at release in MBOS (r = 0.544 – 0.777), with 5 repetition maximums in the lat pull-down test (r = 0.555 – 0.729), and with FINA points (r = 0.783). In the OUAS trial, increases in horizontal velocity from the start of the OUAS to the maximum horizontal velocity correlated with horizontal velocity at the start of trial, and high-level swimmers accelerated their body in a manner that was dependent on horizontal velocity at the start of the OUAS. These results suggest that underwater power output using only the upper limbs is closely associated with power and strength in dry-land exercise, and that back and upper-limb power and strength are crucial physical elements for competitive swimmers.
Keywords: Performance analysis of sport, Physical conditioning, Resistance training, Sport performance, Lat pull-down, Coaching.

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INTRODUCTION

Sprint performance in competitive swimming is directly affected by physical elements, such as strength, power, endurance, and flexibility. Competitive swimmers exercise daily on land to improve these elements. Resistance training to increase strength and power is a key exercise for sprint swimmers (Muniz-Pardos et al., 2019), and its effects on swimming performance have been demonstrated (Aspenes et al., 2009; Crowley et al., 2017; Weston et al., 2015). Regarding the strength and power of swimmers, previous studies reported strong correlations between upper-limb strength and swimming performance (Morouço et al., 2011; Sharp et al., 1982; Smith et al., 2002; Tanaka et al., 1993; Zamparo et al., 2005). Based on these findings, increases in upper-limb strength need to be prioritized by competitive sprint swimmers. However, swimming coaches and swimmers recognize the demerits of implementing resistance training, namely, increases in body mass and decreases in joint range of motion associated with muscle hypertrophy, which negatively affect swimming performance. Therefore, well-trained swimmers who have already achieved high strength and power levels reduce the proportion of basic resistance training accompanied by increases in body mass and implement high-intensity low-volume resistance training or high-power training specific to swimming movements, including dry-land exercise.

Various training methods have been developed to increase the muscle power of swimmers. Typical methods are resisted swimming using parachutes and hand paddles in water (Cortesi et al., 2019; Gourgoulis et al., 2010; Schnitzler et al., 2011; Telles et al., 2011) and dry-land exercise using a swim bench (Strass, 1988; Tanaka et al., 1993) and medicine ball (MB) (Espada et al., 2016; Sarramian et al., 2015). Regarding the kinematic effects of resisted swimming, Gourgoulis et al. (2010) demonstrated the relevance of sprint-resisted swimming because no alterations were observed in the swimming technique, such as the relative pull length or medial-lateral displacement of the hand. Moreover, specific in-water resistance training interventions were found to have a positive impact on performance (Girold et al., 2006; Girold et al., 2007; Ikeda, et al., 2018). Regarding the effects of training on swimming performance, Fone and Tillaar (Fone and van den Tillaar, 2022) suggested that a combined swimming and strength training regimen improved swimming performance more than a swim-only approach to training.

A swim bench is the most commonly used method for dry-land exercise, and its relationship with swimming performance (Sharp et al., 1982), training effects (Tanaka et al., 1993), and kinematic characteristics (Strass, 1988) have been examined. Although the longitudinal training effects of the swim bench for swimming performance currently remain unclear, the importance of movement control and specificity for training exercises in swim-bench training has been emphasized (Crowley et al., 2017). Dry-land exercise using a MB is practiced for core and arm training or testing (Espada et al., 2016; Garrido et al., 2010). Previous studies using a MB investigated the relationship between upper, lower body, and trunk power output and the training effects of throwing movements and suggested its validity and reliability as a total body explosive power test (Ikeda et al., 2007; Ikeda et al., 2009; Kubo et al., 1999; Stockbrugger and Haennel, 2001; Stockbrugger and Haennel, 2003). The greatest advantage of using MB throwing as a dry-land exercise for swimmers is its performance without deceleration in the latter phase of movement, which is beneficial for swimmers. However, limited information is currently available on the relationship between swimming performance and power production during dry-land exercise.

Lat pull-down and pull-up exercises are the most common strength exercises for competitive swimmers. In both exercises, the latissimus dorsi muscle is the agonist muscle (Crate, 1997) and plays an important role during the swimming stroke (Martens et al., 2015). Previous studies investigated the relationship between swimming performance and upper-limb and back strength exercises, such as lat pull-down and pull-up exercises, and suggested that sprint performance was associated with increases in back and upper-limb strength and power by lat pull-down and pull-up exercises (Garrido et al., 2010; Morouço et al., 2011; Pérez-Olea et al., 2018). These findings may become the rationale for the design of strength training exercises for the back and upper limbs of competitive swimmers. However, swimming performance evaluated in previous studies included swimming factors other than strokes, such as the kick, start, and turn. Therefore, it currently remains unclear how the strength and power of the back and upper limbs during dry-land exercise affect underwater stroke power.

Quantitative evaluations of the underwater propulsive force and power of each swimmer will contribute to the development of effective individualized strength training programs based on the identified weaknesses of each swimmer. In competitive swimming studies, there have been many attempts to quantify the forces acting on the body and pushing water (Havriluk, 2005; Hollander et al., 1986; Narita et al., 2017; Narita et al., 2018; Tsunokawa et al., 2019). The findings obtained revealed that wave drag has a negative effect on swimmers as swimming velocity increases (Narita et al., 2017; Tsunokawa et al., 2019; Vennell et al., 2006), and that active drag is proportional to the cube of swimming velocity (Narita et al., 2018). In addition, Narita et al. (Narita et al., 2018) suggested that passive and active drag showed different changes with increases in swimming velocity and this behaviour was associated with the stroke rate. Based on this information, the methods used in these studies are extremely useful for analysing swimming techniques. However, these biomechanical methods may not be practical for assessing underwater power output by the back and upper limbs due to the difficulties associated with measuring propulsive force and active drag during swimming. Therefore, the present study focused on underwater power output in the one underwater arm stroke (OUAS) trial starting from a gliding motion and the strength and power of the back and upper limbs on land in dry-land exercise. A more detailed understanding of the relationship between power output by the back and upper limbs underwater and on land will be useful for developing dry-land exercises that enhance the underwater power output of arm strokes. We hypothesized that an increase in horizontal velocity during OUAS is associated with power output during dry-land exercise using a MB, strength in the lat pull-down exercise, and the competitive level of swimmers. The aim of the present study was to elucidate the relationships among the performance of OUAS, power output in dry-land exercise, and the strength of the upper limbs, and to verify the evaluation of underwater power output by the back and upper limbs in order to confirm the validity of dry-land exercise as a physical training method.

MATERIAL AND METHODS

Participants

Thirteen male Japanese swimmers participated in the present study, including two top-level swimmers (Table 1). FINA points were calculated based on each subject's specialized swimming technique. Subjects regularly raced a short distance of 50-100 m using front crawl and butterfly. They were fully informed of the experimental purpose and procedures of the present study and provided signed informed consent before their participation. All experimental procedures conformed to the Declaration of Helsinki and were approved by the Institutional Review Board at the Niigata University of Health and Welfare (18819-220425).

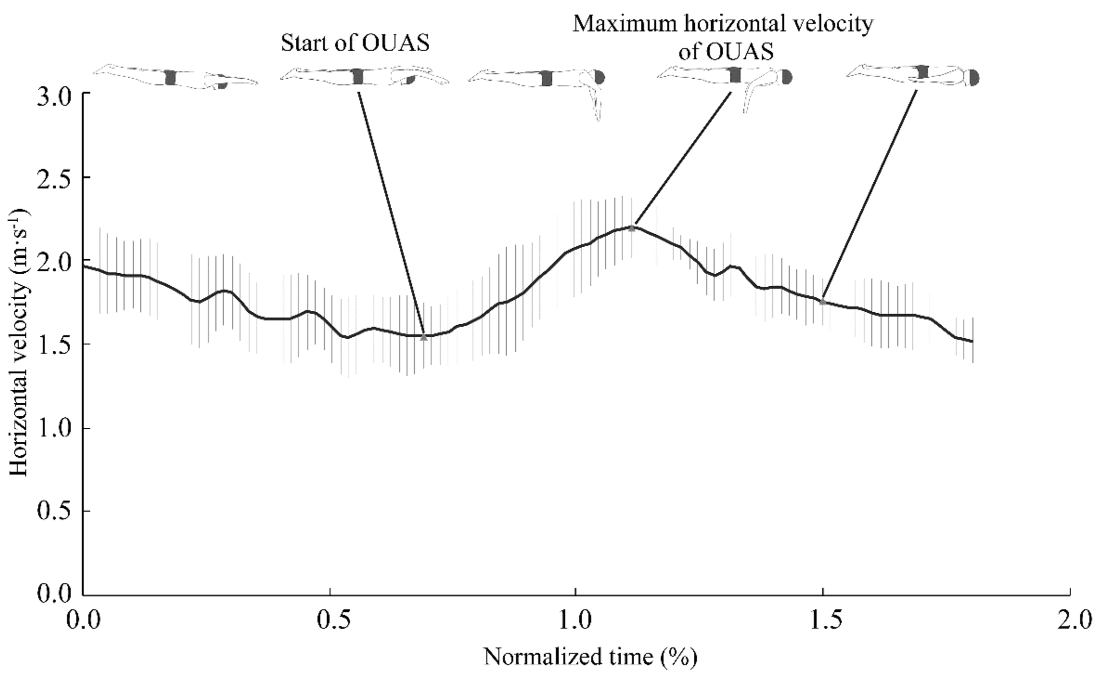
Procedures

To elucidate the relationships between underwater power output in OUAS and the strength and power of the back and upper limbs in dry-land and lat pull-down exercises, 13 male competitive swimmers voluntarily participated in the present study. One week before the medicine ball overhead slam (MBOS) trial, all subjects performed a familiarization session of MBOS using all MB masses because subjects used a 3-kg MB in MBOS as a daily dry-land exercise. The OUAS and MBOS trials were performed on separate days to minimize the effects of fatigue associated with each test. Two-dimensional motion data in these sessions were recorded. A strength test using the lat pull-down machine was conducted after the MBOS trial.

Table 1. Physical characteristics and performance in OUAS and MBOS trials.

Variable	Average ± SD	CV	ICC
Age (yr)	20.31 ± 2.56	-	-
Height (m)	1.75 ± 0.04	-	-
Body mass (kg)	71.80 ± 5.40	-	-
FINA Points	738.40 ± 83.80	-	-
5 RM in the lat pull-down test (kg)	82.40 ± 8.53	0.10	-
Maximum horizontal velocity of OUAS ($m \cdot s^{-1}$)	2.32 ± 0.16	0.07	0.867 ***
Horizontal velocity at the start of OUAS ($m \cdot s^{-1}$)	1.52 ± 0.21	0.14	0.655 **
Increase in horizontal velocity in OUAS ($m \cdot s^{-1}$)	0.80 ± 0.13	0.17	0.006
Vertical velocity of the MB at release in 2-kg MBOS ($m \cdot s^{-1}$)	12.53 ± 0.87 $^{a, b, c}$	0.07	0.709 **
Vertical velocity of the MB at release in 4-kg MBOS ($m \cdot s^{-1}$)	10.55 ± 0.51 $^{b, c}$	0.05	0.858 ***
Vertical velocity of the MB at release in 6-kg MBOS ($m \cdot s^{-1}$)	9.31 ± 0.53	0.06	0.685 **
Vertical velocity of the MB at release in 8-kg MBOS ($m \cdot s^{-1}$)	8.96 ± 0.50	0.06	0.643 **

*Note. Values are presented as means ± SD. ^{a}, significantly greater than 4 kg, ^{b}, significantly greater than 6 kg, ^{c}, significantly greater than 8 kg. OUAS: one underwater arm stroke, MBOS: medicine ball overhead slam CV: coefficient of variance, ICC: intraclass correlation coefficient, RM: repetition maximums. ** p < .01, *** p < .001.*



Note. OUAS: One underwater arm stroke.

Figure 1. Change in average horizontal velocity of the great trochanter from start to finish in the OUAS trial.

The OUAS trial. Underwater maximal power by the back and upper limbs was assessed using the OUAS trial. A light-emitting marker was attached to the greater trochanter (GT) in order to measure horizontal velocity during the OUAS trial. The motion of OUAS was recorded in the sagittal plane using a digital video camera (GC-LJ20B, SPORTS SENSING Co., Fukuoka, Japan) placed perpendicular to the subject's plane of motion. This camera was positioned beneath the deck approximately 4.5 m from the wall of the pool. The sampling frequency was 120 Hz, and the exposure time was set at 1/500 s. A digitizing system (FrameDIAS V, DKH, Inc., Itabashi-ku, Tokyo, Japan) was used to manually digitize GT. The digitizing rate was 60 Hz. Two horizontal control points in water were used to obtain two-dimensional coordinates underwater. To calculate the coordinate value using two horizontal control points with a level in water and on the ground, the horizontal to vertical ratio of the video image was assessed in advance. We then used this ratio to calculate two-dimensional coordinates (Ikeda, et al., 2018; Ikeda et al., 2021). Coordinate values were filtered digitally using a Butterworth-type fourth-order low-pass filter. The cut-off frequency for the two-dimensional coordinates was 6 Hz (Ikeda et al., 2021). Subjects were allowed to perform non-prescribed warm-up exercises for 30 min in a 25-m indoor swimming pool. They then conducted 2–3 × 10 m OUAS at maximum effort. Following the gliding phase after kicking the wall of the pool (no dive), subjects performed OUAS when they passed the 5-m line in water, which was marked at the bottom of pool. In this test, the start and finish movements of OUAS (Figure 1) were identified by video data (60 Hz), and the horizontal velocity of GT at these points and the maximal horizontal velocity of GT during OUAS were recorded. Increase in the horizontal velocity of GT was calculated by subtracting the start velocity of the OUAS from the maximal velocity of the OUAS. The trial that recorded the maximal velocity was selected for analysis. The range of video recording was 8 m (0–8 m from the wall). Trials were repeated after a 3-min period of rest.

The MBOS trial. To measure maximal power output by the back and upper limbs, the MBOS trial was performed using 2-, 4-, 6-, and 8-kg MB (Figure 2). Markings were made on the skin directly over the joint centres of the metacarpophalangeal joint, wrist, elbow, shoulder, the elbow, inferior end of the rib, GT, knee, ankle, and hallux using tape. The motion of MBOS was recorded in the sagittal plane for a motion analysis using a digital video camera (GC-LJ20B, SPORTS SENSING Co., Fukuoka, Japan) placed perpendicular to the subject's plane of motion. The sampling frequency was 120 Hz and the exposure time was set at 1/1000 s. The digitizing rate was 120 Hz. In the MBOS analysis, we assumed that the movement of both the arms and legs of subjects during MBOS was symmetrical; therefore, only one side of a subject's upper and lower limbs recorded by the digital video camera was digitized. In the present study, the lengths of two control points for calibration were used to obtain two-dimensional coordinates underwater. To calculate the coordinate value using four horizontal control points with a level on the ground, the horizontal to vertical ratio of the video image was assessed in advance. We then used this ratio to calculate two-dimensional coordinates (Ikeda et al., 2009; Ikeda, et al., 2018). Coordinate values were filtered digitally using a Butterworth-type fourth-order low-pass filter. The cut-off frequency for the two-dimensional coordinates was 6 Hz (Ikeda et al., 2009). After non-prescribed warm-up exercises for 30 min in a laboratory, subjects performed MBOS using the 2-, 4-, 6-, and 8-kg MB at maximum effort. They conducted 2 trials with each MB mass, if the trial failed, an additional trial was conducted. Trials using the same MB were repeated after a 1-min period of rest, and another trial using a different MB was performed after a 3-min period of rest. The trial for analysis was selected based on the vertical velocity of the MB at release. The motion of MBOS was equally divided into two phases: (i) the first half phase between the starting point at which the angular velocity of the shoulder reached 1 radian·s^{-1} and the middle point (mid-point), which was located between the starting point and release point, and (ii) the second half phase between the mid-point and release point. In the present study, release was defined as the last frame in which subjects were touching the MB. The vertical velocity of the MB as a performance indicator of MBOS was obtained in the next frame of release. In this test, power in the vertical direction for MBOS was calculated as (a) Force = (MB mass × 9.81) + (MB mass × acceleration), (b) Power = force × velocity. Average power was calculated in both the first and second half phases. The angles and angular velocities of the shoulder and elbow were calculated. The centre of mass (CM) was calculated by body segment parameters for Japanese athletes (Ae, 1996).

Note. MBOS: Medicine ball overhead slam.

Figure 2. Movement in the MBOS trial.

Strength testing. The strength of the back and upper-limb muscles was assessed using 5 repetition maximums (RM) in the lat pull-down test. A standard lat pull-down machine (FUNASIS Lat pull-down, BB4322, Senoh, Matsudo, Japan) was used to perform the lat pull-down test. After the MBOS trial, subjects performed a progressive warm-up that consisted of 8 repetitions at 80% of 10 RM and 5 repetitions at approximately 80% of 5 RM. The start load was set at approximately 90-95% of the estimated 5 RM and was increased by 2.5 or 5 kg. Subjects performed 2-3 attempts until 5 RM was achieved. The rest period between attempts was three mins. In the lat pull-down test, each repetition started with the arm fully extended and was completed when the bar was below the chin using the anterior lat pull-down technique (Andersen et al., 2014; Crate, 1997). This test adopted a wide pronated grip (Andersen et al., 2014), which is used in daily resistance training by subjects, and grip width was confirmed by an author who was a certified strength and conditioning specialist. Subjects were instructed to minimize the movement of the hip joint and trunk.

Analysis

Values for each parameter are presented as the mean ± standard deviation. The coefficient of variance (CV) was calculated by dividing the standard deviation by the mean. To assess relationships between variables, Pearson's product-moment correlations were calculated. The Kruskal-Wallis one-way analysis of variance and Mann-Whitney post-hoc tests were used to examine differences in the MBOS trial at different MB masses. Intraclass correlation coefficients (ICC) were used to examine the relationship between trials in the OUAS and MBOS trials. All statistical procedures were conducted with SPSS Statistics 27, and significance was set at $p < .05$.

RESULTS

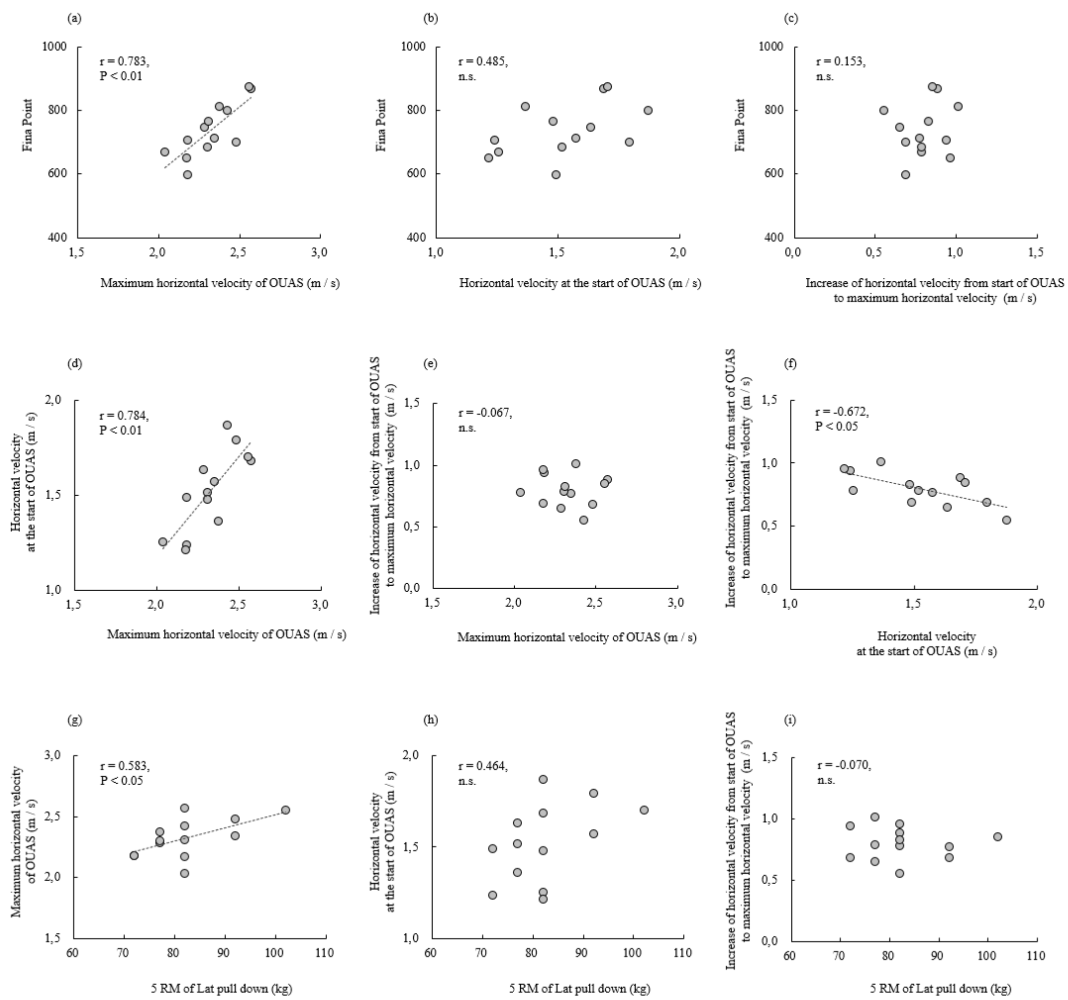
Differences between the actual measurement value of the horizontal distance and that of the horizontal distance calculated from digitized coordinates in the calibration on land for MBOS trial and underwater for OUAS were 0.0047 m and 0.0076 m, respectively.

Table 1 shows the physical characteristics of subjects, FINA points, 5 RM in the lat pull-down test, the performance parameters of the OUAS trial, and the vertical velocity of the MB at release. ICC was used to examine the relationship between the best trial and the second trial in the OUAS and MBOS trials. Apart from an increase in horizontal velocity in OUAS, correlations were observed in these ICC. Regarding the CV of performance parameters in the OUAS and MBOS trials, the CV for the maximum horizontal velocity of OUAS was smaller than those for other performance parameters in the OUAS trial, while only slight differences were noted in CV for performance parameters in the MBOS trial. Figure 3 shows the relationships among performance parameters in the OUAS trial, FINA points, and 5 RM in the lat pull-down test. The maximum horizontal velocity of OUAS correlated with FINA points and 5 RM in the lat pull-down test (Figure 3(a)(g)). Regarding the relationships among performance parameters in the OUAS trial, the maximum horizontal velocity of OUAS correlated with horizontal velocity at the start of OUAS (Figure 3(d)), and horizontal velocity at the start of OUAS negatively correlated with an increase in horizontal velocity from the start of OUAS to the maximum horizontal velocity (Figure 3(f)). The maximum horizontal velocity of OUAS and 5 RM in the lat pull-down test correlated with the vertical velocities of the MB in the MBOS trial (Table 2).

Table 2. Correlations between performance in MBOS and OUAS trials and 5 RM in the lat pull-down test.

Variable	**Vertical velocity at release in MBOS**			
	2 kg	4 kg	6 kg	8 kg
Maximum horizontal velocity of OUAS ($m \cdot s^{-1}$)	0.584 *	0.544	0.777 **	0.684 *
5 RM in the lat pull-down test (kg)	0.590 *	0.729 **	0.672 *	0.555 *

*Note. MBOS: medicine ball overhead slam, OUAS: One underwater arm stroke, RM: repetition maximums. *, ** Significant at p < .05 and p < .01, respectively.*



Note. OUAS: One underwater arm stroke.

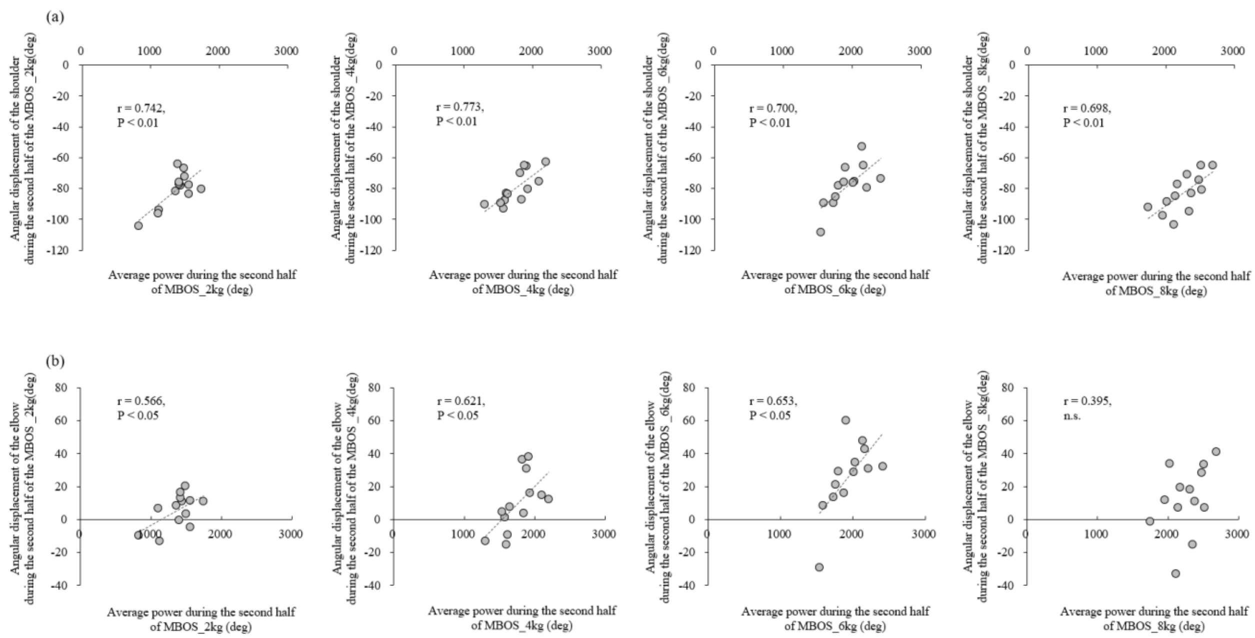
Figure 3. Relationships between OUAS parameters, Fina points, and 5 RM in the lat pull-down test.

Regarding the vertical velocity of the MB at release in the MBOS trial, the Kruskal-Wallis one-way analysis of variance revealed significant differences in the vertical velocities of the MB (Test statistic = 42.324, $p < .001$). Post hoc tests showed that the vertical velocity of the MB in the MBOS trial was significantly greater at 2 kg than at 4, 6, or 8 kg, and significantly greater at 4 kg than at 6 or 8 kg. Furthermore, the vertical velocities of the MB at release did not correlate with those at the mid-point at all MB masses in the MBOS trial (2 kg; r = 0.016, n.s., 4 kg; r = 0.458, n.s., 6 kg; r = 0.218, n.s., 8 kg; r = 0.267, n.s.). The Kruskal-Wallis one-way analysis of variance revealed no significant difference in the angle of the shoulder joint at the start of MBOS (Test statistic = 1.025, $p = .795$), at the mid-point of MBOS (Test statistic = 5.277, $p = .153$), or at release in MBOS (Test statistic = 2.777, $p = .427$). Furthermore, the Kruskal-Wallis one-way analysis of variance revealed no significant difference in the angle of the elbow joint at the start of MBOS (Test statistic = 0.158, $p = .984$) or at the mid-point of MBOS (Test statistic = 2.642, $p = .450$). However, the Kruskal-Wallis one-way analysis of variance revealed a significant difference in the angle of the elbow joint at release in MBOS (Test statistic = 18.999, $p < .001$). Post hoc tests showed that the angle of the elbow joint at release in MBOS was significantly greater at 6 kg than at 2, 4, or 8 kg. The Kruskal-Wallis one-way analysis of variance revealed a significant difference in the angular displacement of the shoulder joint during the first half phase of MBOS (Test statistic = 9.320, $p < .05$). Post hoc tests showed that the angular displacement of the shoulder joint during the first half phase of MBOS was significantly smaller at 6 kg (-45.2 deg ± 7.7) than at 2 kg (-35.2 deg ± 9.3). The Kruskal-Wallis one-way analysis of variance also revealed no significant difference in the angular displacement of the shoulder joint during the second half of MBOS (Test statistic = 1.036, $p = .793$). The Kruskal-Wallis one-way analysis of variance revealed no significant difference in the angular displacement of the elbow joint during the first half phase of MBOS (Test statistic = 2.750, $p = .432$). However, during the second half phase of MBOS, the Kruskal-Wallis one-way analysis of variance revealed a significant difference in the angular displacement of the elbow joint (Test statistic = 9.746, $p < .05$). Post hoc tests showed that the angular displacement of the elbow joint during the second half phase of MBOS was significantly greater at 6 kg (25.8 deg ± 21.75) than at 2 kg (5.6 deg ± 10.10).

The Kruskal-Wallis one-way analysis of variance revealed a significant difference in the horizontal displacement of the CM in the MBOS (Test statistic = 11.502, $p < .01$). Post hoc tests showed that the horizontal displacement of the CM in MBOS was significantly greater at 8 kg (0.050 m ± 0.021) than at 2 kg (0.022 m ± 0.016). Other values for the horizontal displacement of the CM were 0.032 m ± 0.015 at 4 kg and 0.045 m ± 0.020 at 6 kg.

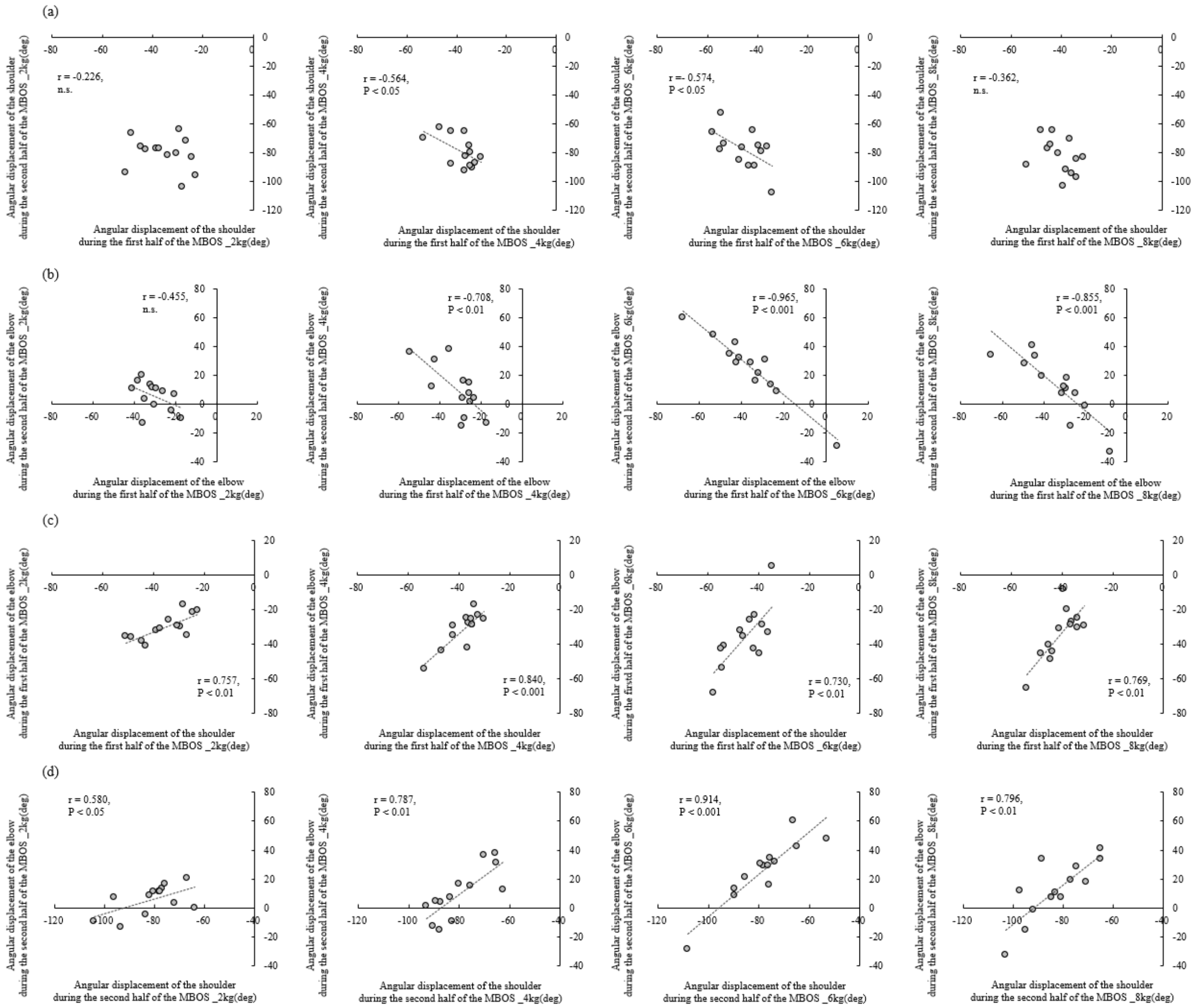
Regarding the relationship between the vertical velocity of the MB at release in MBOS and power exerted on the MB during the first and second half phases, the vertical velocity of the 2-kg MB at release in MBOS did not correlate with average power during the first half phase (r = -0.081, n.s.), but correlated with average power during the second half phase (r = 0.788, $p < .01$). The vertical velocity of the 4-kg MB at release in MBOS did not correlate with average power during the first half phase (r = 0.386, n.s.), but correlated with average power during the second half phase (r = 0.842, $p < .01$). The vertical velocity of the 6-kg MB at release in MBOS did not correlate with average power during the first half phase (r = 0.255, n.s.), but correlated with average power during the second half phase (r = 0.842, $p < .001$). The vertical velocity of the 8-kg MB at release in MBOS did not correlate with average power during the first half phase (r = 0.159, n.s.), but correlated with average power during the second half phase (r = 0.824, $p < .01$).

Figure 4 shows the relationship between average power and the angular displacement of the shoulder (a) and elbow (b) during the second half phase of MBOS. Correlations were observed between average power and the angular displacement of the shoulder and elbow joints during the second half phase of MBOS, except for the angular displacement of the elbow and average power in the 8-kg MBOS trial. Figure 5 shows the relationships between the kinematic values of the shoulder and elbow joints. Correlations were noted between the angular displacement of the shoulder and elbow joints in the first and second half phases, except for the angular displacement of the shoulder in the 2- and 8-kg MBOS trials (Figure 5 (a)(b)). Regarding the relationship between the angular displacement of the shoulder and elbow joints, the angular displacement of the shoulder correlated with the angular displacement of the elbow during the first and second half phases (Figure 5 (c)(d)). Regarding the relationship between the maximum horizontal velocity of OUAS and the angular displacement of the shoulder and elbow joints in MBOS, the maximum horizontal velocity of OUAS correlated with the total angular displacement of the shoulder in the 2-kg MBOS trial (r = 0.654, $p < .05$), 4-kg MBOS trial (r = 0.662, $p < .05$), and 8-kg MBOS trial (r = 0.572, $p < .05$), but not in the 6-kg MBOS trial (r = 0.526, $p = .065$).



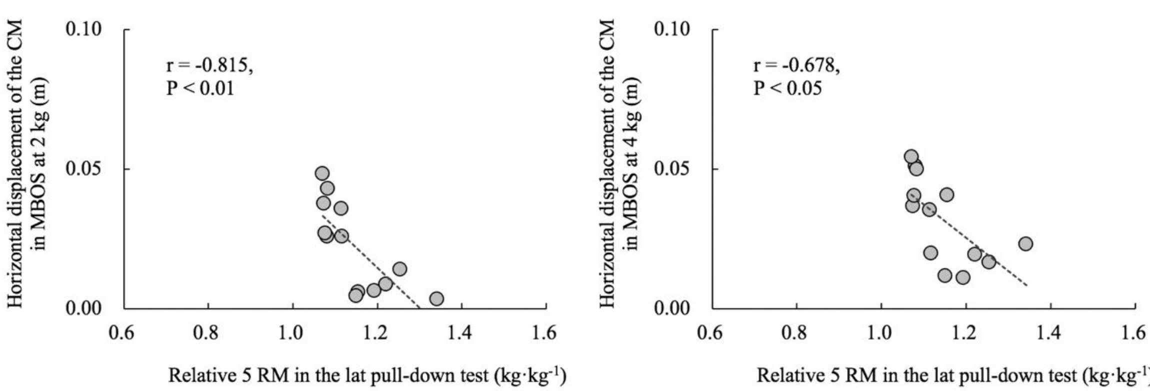
Note. MBOS: Medicine ball overhead slam.

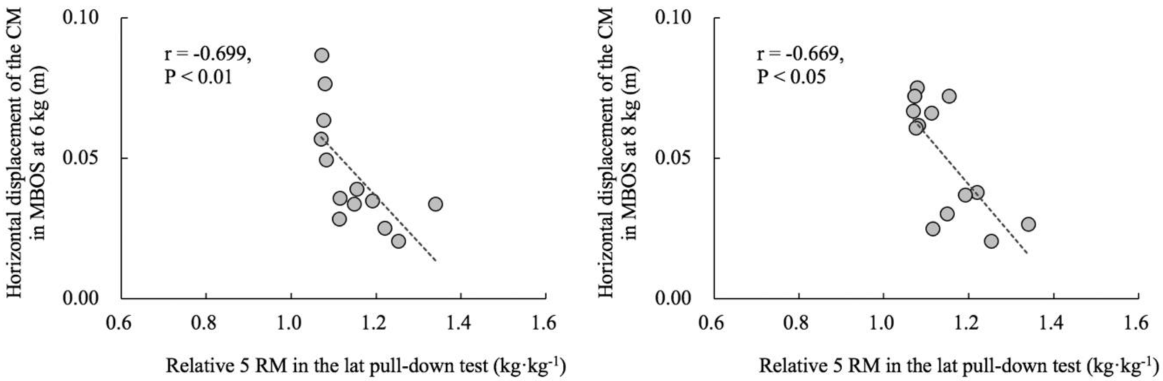
Figure 4. Relationships between average power and angular displacement of the shoulder and elbow during the second half phase of the MBOS trial.



Note. MBOS: Medicine ball overhead slam.

Figure 5. Relationships between the angular displacement of the shoulder and elbow during first and second half phases of the MBOS trial.





Note. CM: Centre of mass, MBOS: medicine ball overhead slam.

Figure 6. Relationship between relative 5 RM in the lat pull-down trial and horizontal displacement of the CM in the MBOS trial.

Figure 6 shows the relationship between relative 5 RM in the lat pull-down test and horizontal displacement of the CM from the start to release in MBOS. Correlations were observed between relative 5 RM in the lat pull-down test and the horizontal displacement of the CM in all MBOS trials.

DISCUSSION

The aims of the present study were to elucidate the relationship between underwater power output by OUAS and strength and power during dry-land exercise and examine a method to assess underwater power output by the upper limbs with the ultimate goal of establishing an approach to evaluate upper-limb power output for competitive swimmers.

The main result of this study was the strong correlation between the maximum horizontal velocity of OUAS, which was used as a predictor of underwater power output by the back and upper limbs, and the performance of dry-land exercise by the upper limbs using a MB. Maximum strength in lat pull-down exercises (Morouço et al., 2011) and power in pull-up exercises (Pérez-Olea et al., 2018) have been shown to correlate with swimming performance. These findings suggest the importance of dry-land exercise by the upper limbs for swimmers, and that the latissimus dorsi muscle, which has the role of adduction, extension, inner rotation, and horizontal extension in the shoulder joint, is closely associated with swimming performance. However, swimming performance evaluated in previous studies included swimming elements other than strokes, such as the kick, start, and turn. To obtain relevant scientific information for the design of effective training programs for dry-land exercise, it is important to elucidate the relationships between each swimming element and strength and power in dry-land exercise. In the present study, high-level swimmers, including elite swimmers, showed faster horizontal velocity during OUAS, and the maximum velocity of OUAS positively correlated with the vertical velocities of the MB at release in MBOS trials (Table 2 and Figure 3). Underwater power output by the back and upper limbs has not yet been evaluated, and the relationships between the performance of OUAS and power and strength in dry-land exercise remain unknown. Therefore, this is the first study to examine power output by the upper limbs in water and on land. The results obtained support the validity of the evaluation approach for underwater power output by the upper limbs and suggest the importance of enhancing power output by the back and upper limbs for competitive swimmers.

Regarding the relationship between the vertical velocities of the MB and the power exerted on the MB in the MBOS trials, the vertical velocities of the MB at the mid-point did not correlate with those at release for any MB mass. Furthermore, the vertical velocities of the MB at release correlated with average power during the second half of MBOS at all MB masses, while no correlations were observed between the vertical velocities of the MB at release and average power during the first half phase. These results suggest that the vertical velocities of the MB at release were determined by average power output during the second half phase regardless of the MB mass.

The small angular displacement of the shoulder and greater angular displacement of the elbow during the second half phase led to greater average power in MBOS (Figure 4). In addition, the total angular displacement of the shoulder from the start point to release, which correlated with the angular displacement of the shoulder during the second half phase, negatively correlated with the maximum horizontal velocities of OUAS. In order to understand the skilled movements of the shoulder and elbow to generate power, Figure 5 shows the relationships among the angular displacement of the shoulder and elbow during the first and second half phases of MBOS. The results obtained showed that the shoulder functioned in concert with the elbow to generate power and suggested that subjects need to extend the shoulder and flex the elbow during the first half phase of MBOS and slightly extend the shoulder and markedly extend the elbow during the second half phase. Furthermore, small extension of the shoulder was associated with great extension of the elbow during the second half phase (Figure 5(d)). In MBOS, which involves the extension and adduction of the shoulder and extension of the elbow, the latissimus dorsi muscle, greater pectoral muscle, and triceps brachii muscle are agonist muscles. Considering these kinematic results and the role of the agonist muscles, it is speculated that the triceps brachii muscle plays a role in power output because the long head of the triceps brachii muscle is a biarticular muscle involved in extension of the shoulder and elbow. Thus, the restriction of the angular displacement of the shoulder for extension by the long head of triceps brachii muscle during the second half phase of MBOS may contribute to the greater extension of the elbow. These kinematic data may be useful for optimizing upper-limb underwater movement to exert propulsive force and instructions on movements during dry-land exercise.

Regarding the different MB masses, the vertical velocities of the MB at release significantly decreased with increasing the MB mass, while no significant differences were observed in the vertical velocity of the MB at release between 6 and 8 kg. Furthermore, the MB mass altered the relationships between the vertical velocities of the MB, the maximum horizontal velocity of OUAS, and 5 RM in the lat pull-down test (Table 2). The highest correlation coefficients were observed at 4 kg (5 RM in the lat pull-down test) and 6 kg (maximum horizontal velocity of OUAS). Regarding the mass of the MB used in resistance training, Ikeda et al. (Ikeda et al., 2007; Ikeda et al., 2009) suggested selecting an appropriate MB mass based on the fitness levels of athletes. The present results suggest that 4-kg or 6-kg MB was a valid mass for our subjects, who achieved high strength levels for 5 RM in the lat pull-down test (range: 72-102 kg). Regarding the kinematic parameters of the shoulder and elbow during MBOS, a significant change was not observed with an increase in the MB mass. The horizontal displacement of the CM during MBOS increased at greater MB masses, which indicated that the CM moved backwards from the start to release in MBOS. Since it is important for swimmers to implement dry-land exercise in consideration of a posture that reduces underwater resistance, the horizontal movement of the body during MBOS needs to be assessed by swimming as well as strength and conditioning coaches.

The strength of the back and upper limbs measured by the lat pull-down test correlated with the performance of OUAS and MBOS. In addition, relative 5 RM in the lat pull-down test correlated with the horizontal displacement of the CM in MBOS (Figure 6). These results suggest that the basic strength of the back and upper limbs was associated with power output underwater and on land, and that swimmers with high relative strength in the lat pull-down test maintained their body position during the MBOS movement. Since body position has an impact on swimming performance, swimming as well as strength and conditioning coaches need to consider the effects of the strength of the back and upper limbs on underwater posture and body position, and also focus on a swimmer's posture during dry-land exercise. The positive relationships between strength and power in lat pull-down and pull-up exercises and swimming performance demonstrates the importance of the strength of the back and upper limbs for competitive swimmers (Garrido et al., 2010; Morouço et al., 2011; Pérez-Olea et al., 2018). Pérez-Olea et al. (Pérez-Olea et al., 2018) suggested that sprint swimmers need to enhance maximum strength, not muscular endurance, in pull-up exercises. Based on previous findings, increases in the strength of the back and upper limbs using different muscular contraction types and training postures in various training exercises will improve sprint swimming performance. Furthermore, it may be important for swimming and strength coaches to adopt a concept that connects basic strength and power in typical resistance exercise and specific strength and power in dry-land exercise to enhance underwater power output.

One of the main results in the present study was the negative correlation between horizontal velocity at the start of OUAS and the increase in horizontal velocity from the start of OUAS to the maximum horizontal velocity (Figure 3 (f)). We hypothesized that high-level swimmers may acquire great horizontal velocity of the OUAS by greatly increasing the horizontal velocity from start of the OUAS to the maximum horizontal velocity. However, the results obtained showed that the increase in horizontal velocity was influenced by horizontal velocity at the start of OUAS, and high-level swimmers accelerated the body in a manner that was dependent on horizontal velocity at the start of OUAS. Regarding the relationship between swimming velocity and drag, Narita et al. (Narita et al., 2018) suggested that the effects of active drag increased at higher swimming velocities and highlighted the importance of underwater power output at a high velocity. Although OUAS has not yet been examined as a predictor of underwater power output, the results of the present study, including the relationship between the maximum velocity of OUAS and FINA points, demonstrate the validity of the method to evaluate underwater power output, and suggest that OUAS, which alters velocity at the start of OUAS, is effective underwater power training for the back and upper limbs.

There were several limitations that need to be addressed. A motion analysis of OUAS was not conducted and differences were noted in velocity of the start of OUAS. Therefore, the impact of kinematic characteristics during OUAS and horizontal velocity at the start of OUAS on performance are unknown. An experiment that uses a common horizontal velocity at the start of OUAS may provide useful information for dry-land exercise. Future studies are needed to examine the movement of OUAS at different horizontal velocities at the start of OUAS.

CONCLUSIONS

The present study showed that the performance of OUAS has potential as a predictor of underwater power output for competitive swimmers, and that this underwater power output is associated with strength and power measured by the lat pull-down test and in the MBOS trial. Furthermore, the results of the present study suggest a relationship between performance and the kinematic characteristics of the upper limbs in the MBOS trial. The results obtained also indicate the importance of increasing basic strength by typical resistance training and specific power by dry-land exercise focused on swimming techniques. In the design of training exercises for competitive athletes, the validity and objectivity of each exercise are essential for an exercise to be adopted in programs. Therefore, these results will be useful for swimming as well as strength and conditioning coaches.

AUTHOR CONTRIBUTIONS

The idea for this study and the study design were proposed by Ikeda. Ikeda analysed the data and drafted the manuscript. Nara, Baba, Yamashiro, and Hisamitsu performed measurements. Shimoyama critically reviewed the manuscript.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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SCIENTIFIC JOURNAL OF SPORT AND PERFORMANCE

ORIGINAL ARTICLE

Effects of a controlled exercise programme on anthropometric parameters, dietary habit and sleep quality of obese university students

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ABSTRACT

According to the World Health Organization, obesity has reached epidemic proportions globally. In spite of growing public awareness of the importance of weight loss, obesity prevalence continues to rise with at least 2.8 million people dying each year as a result of being overweight or obese. The main objective of this study was to investigate the effects of jogging exercise programme (JEP) on anthropometric parameters, dietary habit and sleep quality of obese Ghanaian university students. This randomised controlled study employed 33 obese (BMI > 30 kg/m^2) students from a tertiary university in Ghana. The experimental group participated in a six-week, 3-5 times/week JEP for 45 and 40 minutes per session while the control group had intervention free session. Anthropometric parameters were assessed using the Omron body composition analyser and a standard tape measure. Sleep quality and Dietary habit were determined using a pre-validated Sleep Quality Scale and Performance of a Brief Dietary Assessment and Intervention tool for Health Professionals questionnaire respectively. The participants had a mean age of 21.70 ± 3.74 years. There were 14 (42.4%) males and 19 (57.6%) females of which 26 (80.8%) were indigenous and 7 (19.2%) were international students. There was significant decrease in body mass index, waist to hip ratio, and visceral fat; and increase in sleep quality ($p < .05$) at the end of the intervention period. However, the dietary habit of the experimental group did not change significantly ($p > .05$). In conclusion, JEP has positive impacts on anthropometric parameters and sleep quality of obese persons.

Keywords: Sport medicine, Physical exercise, Visceral fat, Waist to hip ratio, Jogging exercise programme, Obesity.

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INTRODUCTION

Individuals with body mass index (BMI) of more than 30.0 kg/m^2 are classified as obese according to the World Health Organisation. (Peven et al., 2020). Obesity is a major public health problem that has attracted considerable attention worldwide. The global prevalence of obesity has more than doubled since 1980, affecting 107.7 million children and 603.7 million adults in 2015, with more than two-thirds of the United States population being overweight or obese *(*O'Donoghue et al., 2020). Across South Asia and Sub-Saharan Africa, 1-in-5 adults have a BMI greater than 25kg/m^2 (Muramoto et al., 2014). The prevalence of obesity has tripled over the past 35 years and it is estimated that it will affect over one billion people worldwide by 2030 *(*O'Donoghue et al., 2020).

Obesity is a known risk factor associated with the development of chronic conditions including hypertension, hyperlipidaemia, hyperglycaemia, chronic hypoxemia, some types of cancer, sleep apnoea and degenerative joint diseases (Park et al., 2003). Obesity also adversely impacts on the quality of sleep which consequently affect cardiovascular and metabolic markers (Basnet et al., 2016).

The rapid surge in obesity is driven mainly by lifestyle factors such as physical inactivity and unhealthy dietary choices (Afshin et al., 2017; McHill and Wright, 2017). The fundamental cause of excess weight gain is the failure to ensure a balance between energy intake and energy expenditure (Bhutani et al., 2021). It has been reported that factors including increased consumption of energy dense poor nutrient foods contributes towards the development of obesity and metabolic syndrome (Ashizawa et al., 2014). A sedentary lifestyle negatively affects physical fitness in persons with obesity. Studies of the fitness levels of those with obesity, although not quite enough, indicate that aerobic and anaerobic exercise levels are much lower in persons living with obesity (Zouhal et al., 2020). Although the factors influencing a compromised performance in the population with obesity remain unclear, there is a consensus that excess body fat and sedentary lifestyles remain important factors to consider in developing intervention programme (Zouhal et al., 2020).

Exercise and physical activity do not only help to reduce the risk of chronic diseases, but also improve sleep quality (Monteiro et al., 2014). According to a behavioural construct, good sleep health is characterized by subjective satisfaction, appropriate timing, adequate duration, high efficiency, and sustained alertness during waking hours (Buysse, 2014). It is typically, but not necessarily, accompanied by postural recumbence, behavioural quiescence, closed eyes, and all the other indicators one commonly associates with sleeping.

In a cross-sectional study in Japanese females (Katagiri et al., 2014), poor sleep quality was found to be significantly associated with consumption of energy drinks and sugar-sweetened beverages, skipping breakfast, and eating irregularly. The study further suggested that unhealthy food habits may be associated with insomnia symptoms, and prospective weight gain in individuals with sleep disorders. Thus, the crosstalk between sleep quality and metabolism plays a key role in the regulation of food intake and energy balance, affects obesity development and should be taken into account in both obesity treatment and prevention (Basolo et al., 2021; Katagiri et al., 2014).

Sleep is therefore an indicator of health status in both diseased and general population (Miró et al., 2008). The effects of sleep are not limited to the body when in need of neurological restoration, but on normal development, functioning of cognitive and intellectual capabilities and good quality of life (Miró et al., 2008). Epidemiological studies have reported an inverse relationship between sleep duration and body mass index (Hursel et al., 2013; Patel, 2009). Potential mechanisms linking poor sleep to obesity and cardio-metabolic risk include up regulation of appetite and reduced motivation to be physically active (Knutson and Cauter, 2008; Quist et al., 2016). Evidence suggests that short sleep duration, poor sleep quality, and irregular sleep patterns are associated with increased risk of obesity and the metabolic syndrome (Schmid et al., 2015).

The treatment for obesity consists primarily of an improvement in eating habits and increased physical activity (Jacob and Isaac, 2012; Klem, et al., 1997; Nordmo et al., 2020). While treating obesity, major emphasis should be directed towards increasing regular physical activity and supported with dietary interventions. By this approach the risk of other chronic diseases often associated with obesity could be minimized thereby improving the quality of life (Jacob and Isaac, 2012).

A recent study among 4393 reproductive female students of higher institution in Ghana showed that 31.1% and 22.4% were overweight and obese respectively (Killian et al., 2021). The authors revealed that the prevalence of obesity in Ghana may be associated with multiple factors such as socio-economic, lifestyle and biological factors, environmental factors such as physical proximity to fast food outlets.

Jogging is an outdoor physical activity mostly used to stay active, fit and healthy particularly in Ghana. Early morning jogging is a very popular physical activity in Ghana especially on weekends. Although there has been research on overweight and obesity related interventions, no attention has been placed on jogging exercise programme. Scientific report of the effectiveness of jogging exercise programme will significantly complement existing practices.

The present study seeks to broaden the knowledge depth on interventions to manage obesity among university students in Ghana. Also, the study will make available information on weight management as well as helping to reduce obesity related problems among students. This study therefore seeks to investigate jogging exercise programme; its effect on dietary habits, anthropometric parameters and the sleep quality of obese persons in a university in Ghana.

MATERIAL AND METHODS

Research design

The study employed a randomized control design to assess the effect of jogging exercise programme (JEP) on the anthropometric parameters, dietary habits, and sleep quality of obese university students.

Participants

The study involved thirty-three obese university students who were recruited regardless of their college, programme and level of study. Purposive and randomized control sampling techniques were used to recruit and assign the participants. The participants were initially invited for voluntary health screening and advice programme at the main university campus. During the health advice session, about ten percent (33) of those with BMI of 30 kg/m^2 and above initially indicated interest to join any beneficiary exercise programme session. They were thereafter contacted for jogging exercise programme. Out of the 33 obese students, 26 consented to participate in a six-week jogging exercise programme while 7 declined due to study workload but agreed to serve as control for the study. All participants were taken through all the test and training protocols before the start of the study and completed an informed consent form prior to the commencement of the study. Participants were informed that participation is voluntary and that they exercise the prerogative right to withdraw from the study without having to provide any reasons.

Measurements

Demographic characteristics of the participants such as age, gender, year of study, ethnicity were obtained.

Anthropometric parameters
Omron Body Composition Monitor and Scale with Seven Fitness Indicators Model: HBF-514C (Omron Healthcare Co. Ltd., Kyoto, Japan) was used to measure the anthropometric parameters such as body fat percentage, body mass index (BMI), skeletal muscle, resting metabolism, visceral fat, and body weight. Waist and hip circumference were measured using a standard tape measure. The measured waist circumference and hip circumference of the participants was used to calculate their Waist to hip ratio (WHR), using the formula: WHR = waist circumference/hip circumference.

Sleep quality assessment
Sleep quality scale designed by Yi et al. (2006) was used to assess the participants' subjective sleep quality. A total score is between the range of 0 – 84 (28 items and a 4-point Likert scale was used, that is 0, 1, 2, 3 and interpretation of rarely, sometimes, often and almost always respectively). Higher scores represented more difficult sleeping problems. Lower scores denote high sleep quality or little or absence of sleeping difficulties. The scale has a consistency level of 0.92 and test-retest reliability of 0.81 from previous research (Digdon and Landry,2013). However, the current study proved to have a Cronbach alpha of 0.78 indicating the scale is highly reliable. Examples of some questions the scale assess are; I have difficulty falling asleep, I fall into deep sleep, poor sleep gives me headache.

Dietary habit
Dietary habit was measured with the Performance of a Brief Dietary Assessment and Intervention Tool for Health Professionals (Paxton et al., 2011). The scale contains 10 questions with 4 responses (1, 2, 3, and 4), total scores ranges from 10 to 40. The author's interpretation to the score is that 10-19 represent poor dietary habits, 20-29 represent fair, 30-39 represent good dietary habits and 40-50 corresponds to excellent dietary habits. The scale with the current study had a Cronbach alpha of 0.69, indicating high reliability. Examples of the questions in this scale are; How many servings (1 serving = 1/2 cup) of fresh, canned, frozen or dried fruit did you eat each day? How many times a day did you eat fast/fried food/or packaged snacks high in fat/salt/or sugar? How would you rate your overall habits of eating healthy foods?

Intervention
Anthropometric parameters, dietary habit and sleep quality of the participants were determined before and after the six weeks jogging exercise programme (JEP) to help establish any changes in research variables.

JEP sessions for the participants included a warmup and cool down of 10 minutes each, followed by 45 minutes of a combination of different types of jogging (Base, Long, Recovery, Sprint, Fartlek, Progression, Hill repeats, Tempo and Intervals) 3 times a week (Monday, Thursday and Saturday) for the first two weeks. From week 3 to 6, the JEP duration was reduced to 40 minutes and frequency increased to 5 times a week (Monday, Tuesday, Thursday, Friday and Saturday) with the same types of jogging. Each of the JEP sessions took place every morning (5:00am-7:00am). Studies have established the efficacy of the various types of jogging (Kurz et al., 2000). Details of the JEP is presented in Table 1.

The seven participants in the control group did not participate in any exercise session and were instructed not to embark on any form of exercise. They were however monitored and restricted only to activities of daily living during the period of the study.

The study was approved by the authors' institutional Research Ethics Committee (Number: CHRPE/AP/582/21).

Table 1. Jogging exercise programme.

Week	Warm-up/cool down	Type	Frequency	Duration
Week 1	10 Minutes	Jogging: Base, Long, Recovery, Sprint, Fartlek, Progression, Hill repeats, Tempo, Intervals	3	45 Minutes
Week 2			3	45 Minutes
Week 3			5	40 Minutes
Week 4			5	40 Minutes
Week 5			5	40 Minutes
Week 6			5	40 Minutes

Data analysis

IBM Statistical Package for Social Sciences (SPSS) version 21.0 was used for data entry and analysis. Descriptive statistics on participants' demographics was done. T-test was used to determine the effect of the exercise programme on research variables. Statistical significance, *p* was set at .05.

RESULTS

Demographic characteristics

Table 2. Demographic characteristics of participants.

Variables	Frequency (n = 33)	Percentage (100%)
Age group (years)		
16-20	11	33.3
21-25	17	51.52
Above 25	5	15.15
Total	33	100
Year of Study		
First year	5	15.15
Second year	7	21.21
Third year	9	27.77
Final year	12	36.36
Total	33	100
Sex		
Male	14	42.40
Female	16	57.60
Total	33	100
Student status		
Indigenous student	26	78.80
International student	7	21.20
Total	33	100
Any family history of obesity?		
Yes	15	45.50
No	18	54.50
Total	33	100

Participants' minimum and maximum ages were 17years and 25years respectively with a mean age of 21.70 ± 3.74 years. First years, second years, third years and final years accounted for 5 (15.15%), 7 (21.21%), 9 (27.27%) and 12 (36.36%) respectively. There were 14 (42.40%) males and 19 (57.60%) females. Twentysix (80.8%) were indigenous students and 7 (19.2%) were international students, 45.50% had a family history of obesity whiles 54.55% had no family history of obesity. Participants' demographic characteristics are represented in Table 2.

Effect of JEP on anthropometrics, dietary habits and sleep quality

Pre and post data analysis of experimental and control groups variables are presented in Table 3 and 4 respectively. T-test analysis showed a significant decrease in all anthropometric and sleep quality parameters (*p* < .05) except for dietary habits (*p* > .05) in the intervention group. However, the controlled group showed no significant difference in the anthropometrics and the dietary habits (*p* > .05) but not so with the sleep quality which showed significant improvement (*p* < .05) although the percentage of improvement is not compared to the experimental group.

Table 3. Pre-post analysis of experimental group.

Variable	Pre-Test	Post-Test	Mean Diff. ± SD	%Diff	SEM (95% CI)	T-value	*p*-value
	Mean ± SD						
BMI	33.04±2.71	31.46±2.45	1.57±1.27	4.75	0.25(2.09-1.06)	6.321	.00
Sleep quality	1.31±0.29	0.81±0.12	0.50±0.30	38.44	1.63(17.50-10.80)	8.700	.00
Dietary habits	27.88±3.17	28.23±3.33	-0.35±3.78	1.25	0.74(1.18-1.87)	-0.472	.645
Visceral fat	10.31±3.16	8.54±2.30	1.77±1.73	17.16	0.34(2.47-1.07)	5.225	.00
Waist to hip ratio	0.86±0.03	0.83±0.04	0.02±0.03	2.33	0.01(0.03-0.01)	4.283	.00

Table 4. Pre-post analysis of control group.

Variable	Pre-Test	Post-Test	Mean Diff. ± SD	%Diff	SEM (95% CI)	T-value	*p*-value
	Mean ± SD						
BMI	33.14±3.44	33.14±2.61	-0.57±1.72	1.72	0.65(1.02-2.16)	0.880	.413
Sleep quality	1.46±0.16	1.29±0.22	0.17±0.12	12	1.27(8.11-1.89)	3.930	.008
Dietary habits	26.29±3.20	27±2.31	-0.71±4.92	2.70	1.86(3.83-5.26)	-0.384	.714
Visceral fat	9.86±2.73	10.43±2.23	0.00±1.41	0.00	0.53(1.31-1.31)	0.000	1.000
Waist to hip ratio	0.85±0.04	0.85±0.04	0.01±0.02	1.18	-0.01(0.02-0.01)	0.63	.555

DISCUSSION

The main objective of this study was to investigate the effects of jogging exercise programme on anthropometric parameters, dietary habits and sleep quality of obese students in a Ghanaian university.

The findings from this study reveal that, the anthropometric parameters such as visceral fat, Body Mass Index and Waist to Hip ratio decreased significantly in obese students after undergoing 6 weeks structured jogging exercises programme (*p* = .00). A control group of the same population found no significant difference in their anthropometry: BMI (*p* = .413), WHR (*p* = .555) and visceral fat (*p* = 1.000).

In conformity with the present study, a similar study by Fett et al. (2008) reported that total body mass, BMI, body fat percentage from anthropometry, body fat percentage by BIA, as well as WHR were significantly reduced in the intervention group after a 6-week jogging programme.

Zouhal et al. (2020) also reported that both aerobic (e.g., endurance training) and anaerobic training (e.g., high-intensity training, resistance training) improved body composition and physical fitness indicators in adults, adolescents and children with obesity. They suggested that both low- and high-intensity training significantly reduced body weight and fat mass while increasing fat-free mass in individuals with obesity.

Again, findings from the current study is similar to the study conducted by Wouters et al. (2010). The authors found that, total fat mass and waist circumference decreased by 1.4 kg (p = .03) and 3.1 cm (p = .005), respectively. The authors concluded that jogging was associated with reduced body fat, waist circumference and improved aerobic fitness and quality of life.

From the study, sleep quality proved to be significantly affected positively by JEP as seen in the exercise group with an average sleep quality score of 1.31 (pre-test) to 0.81 (post-test) which denote sleep pattern with rare to few sleep problems. The control group likewise showed significant improvement in their sleep quality which could be attributed to the physical activity level of the participants as a result of their daily lifestyle choices that were not controlled for in this study. The exercise group however was affected by the JEP as results showed higher significance level of change. JEP therefore can effectively help to reduce the sleep problems that is associated with obese students.

Among other studies which have shown significant effects of physical activity on the sleep quality of obese persons, Brand et al. (2010) investigated whether chronic vigorous exercising is related to improved sleep and psychological functioning. Results showed that, compared with controls, athletes in the experimental group reported better sleep patterns including higher sleep quality, shortened sleep onset latency, and fewer awakenings after sleep onset, as well as less tiredness and increased concentration during the day. In another study, Kredlow et al. (2015), who examined the effects of acute and regular exercise on sleep quality reported that regular exercise has moderate beneficial effects on sleep quality, which is in conformity with the present study.

The study revealed no significant difference in the dietary habits of both the exercise group and the control group though there was an improvement in the scores of both groups. This means that the 6 weeks JEP did not significantly improve the dietary habit of the participants. A study by Vizuete et al. (2012) about the relationship between the physical activity levels and diet quality of a group of young adults from Madrid revealed that active individuals follow healthier diets habit and keep a more adequate body weight. The authors clearly concluded that, when an individual exercises or live an active lifestyle, it increases the metabolic rate and hence force them to select foods that are energy yielding. In other words, the lower the physical activity level the poorer the dietary habit. Contrary to this finding, the current study found no significance difference in the dietary habits of the participants and may be because most of the participants were living sedentary lives prior to the intervention of this study. In addition, the six weeks intervention of this study might not be long enough to effect changes in the dietary habits of the participants.

Another study conducted by Joo et al. (2019) examined the effect of a 15-week exercise training programme on overall dietary patterns among young obese adults. Results showed that, within each of the seven dietary patterns identified, most dietary pattern scores decreased following exercise training, consistent with increased voluntary regulation of food intake. A longer duration of exercise was associated with decreased preferences for the western and snacking patterns, while a higher intensity of exercise was linked to an increased preference for the western and snacking patterns. The current study on the contrary showed no significant effect on the dietary habits of the participants and this could possibly be as a result of the differences in the exercise duration and the study population as well as the geographical location of the participants.

CONCLUSION

In conclusion, the major findings of the present study were that there was a clear dose-response effect observed between amount of 6-week JEP and amount change of anthropometric parameters such as visceral fat, waist to hip ratio and body mass index. The finding also establishes significant change in the sleep quality of the participants. JEP, however, did not improve the dietary habits of the participants significantly. Findings from this study suggest that a modest amount of JEP can control the anthropometrics and improve sleep quality of obese persons with no changes in dietary habits and may lead to important weight loss in obese individuals. Future research should look into comparing JEP and other exercise programmes to establish how different they could affect the anthropometric parameters, dietary habits and sleep quality of obese persons. Similar research should be conducted with larger sample size and longer exercise duration to be able to generalize widely. The current study did not take into consideration the genetic and other biological factors that influence obesity status. Future researches can however look at how individuals who are genetically predisposed to obesity could be controlled biologically.

AUTHOR CONTRIBUTIONS

Conception and design (Adams, C. ,Oppong, P. and Moses, M.O.). Implementation of exercise protocol and data collection (Oppong, P., Worlanyo, J.K., Agblo, S.P., Owusu, S., Addo, E.). Formal analysis and interpretation of data (Oppong, P., Worlanyo, J.K., Agblo, S.P., Owusu, S., Addo, E.). Supervision (Adams, C. and Moses, M.O). Writing of original draft (Adams, C. and Oppong, P.). Writing, review and final editing (Adams, C. , Oppong, P. and Moses, M.O).

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors. The experiment complies with the current laws of Ghana and was given ethical approval by the researchers institution.

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SCIENTIFIC JOURNAL OF SPORT AND PERFORMANCE

REVIEW ARTICLE

Home-fitness and active ageing: A review

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ABSTRACT

The global aging of the population will lead to an increase in social and economic demands, so keeping the elderly active has become a priority. According to the WHO Guidelines, regular physical activity is essential for staying active and healthy and often the best opportunity to do this is at home. Strength activities are frequently set aside because they are considered useless or even risky, but on the contrary have great importance for maintaining of the physical well-being Home-Fitness is an excellent effective and accessible tool for everyone because it brings benefits on a physical and cognitive level, while staying at home. The objective to deepen all aspects related to physical exercise at home in ageing, through a systematic review of the scientific literature, investigating what are the evidence of greatest interest. The evidence determines in depth the relationship between physical activity at home and the elderly, concluding that, those who exercise regularly have a higher quality of life compared to less active subjects. The current COVID-19 pandemic should serve as an impetus for progress in this field.
Keywords: Frailty, Older adults, Ageing, Exercise, Prevention, Home-based.

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INTRODUCTION

The World Health Organization (WHO) confirms that from 2000 to 2019, global life expectancy, considering both men and women, increased by 5.5 years, from 66.5 to 72 years. By 2050 the elderly over 65 will exceed adolescents and young people between 15 and 24 years (United Nations, 2019) and constituting 31.3% of the population compared to 20.2% in 2019. (EUROSTAT)

As the WHO asserts: "*the global aging of the population will entail social and economic demands that will have to be met, so keeping the population active is a necessity and not a luxury*". Active aging, defined by the WHO as "*a process of optimizing opportunities relating to health, participation and safety, with the aim of improving the quality of life of elderly people, becomes extremely important.*" To emphasize the importance of the theme, the "*Decade of Healthy Aging*" was inaugurated, that is the decade dedicated to healthy aging that will cover the period from 2020 to 2030.

The term aging refers to the loss of the body's ability to maintain its homeostasis, that is, the body is no longer able to respond and adapt to changes in the internal and external environment and to maintain its balance. This inefficiency leads to the appearance of modifications that in the long run end with the functional decay of the organism itself and consequently a programmed death. (Clegg, Young, Iliffe, Rikkert, & Rockwood, 2013) According to the definitions officially adopted to date, a person who has reached the age of 65 is considered elderly but the proposal that comes from the Italian Society of Geriatrics and Gerontology (SIGG) is to update the concept of seniority, bringing to 75 the ideal age to define a person as elderly, because "*individuals with the same chronological age vary widely in terms of health and function*." (Mitnitski, Graham, Mogilner, & Rockwood, 2002)

If aging is a physiological condition, a sedentary lifestyle is not. Often the use of motor skills is progressively reduced, until a hypokinetic or even akinetic picture is reached. Scientific evidence reports that elderly people often do not engage in physical activity, not for physical problems, but for fear of failure, unawareness of the potential benefits related to movement and because they feel active even if they are not. (Costello, Kafchinski, Vrazel, & Sullivan, 2011) Physical activity is an indispensable means not only to counteract the negative effects of frailty and limit the loss of autonomy, but also to give motivation, self-esteem, psychological well-being and increase the perception of autonomy of the elderly. Professionals who work in old age must pay particular attention to the motivational aspect, but above all increase self-awareness and minimize the perceived risks associated with carrying out activities. (Franco, et al., 2015) (Baert, Gorus, Mets, & Bautmans, 2015) (Schutzer & Graves, 2004)

Inactivity has serious negative effects on health across the lifespan (Harridge & Lazarus, 2017) and to confirm the importance of movement for the elderly population, guidelines on physical activity have been defined by the WHO, according to which, in order to improve cardiorespiratory and muscular health and reduce the risk of chronic diseases and the cognitive decline, people over 65 should have at least 150 minutes per week of moderate-intensity aerobic physical activity or at least 75 minutes of vigorous-intensity aerobic physical activity or an equivalent combination of both (they can be accumulated, i.e. activities can be carried out for shorter periods of at least 10 minutes each). It is also recommended to combine strength exercises of the major muscle groups at least twice a week, also focusing on activities aimed at improving balance and preventing falls for at least 3 times a week. Strength activities are frequently set aside because they are considered useless or even risky, but on the contrary have great importance for maintaining of the physical well-being (Montero-Fernández & Serra-Rexach, 2013) and increasing life expectancy. (McLeod, Breen, Hamilton, & Philp, 2016) The professional who follows the user will have the task to understand which is the point below which the exercise is not effective and above which one can incur injuries or put the health of the subject at risk. "*Isotonic contractions are preferable to isometric ones, especially for those who suffer from arterial hypertension and who would be negatively affected by carrying out work that brings a further increase in pressure, hindering the circulation."* (Federici, Valentini, Tonini, & Cardinali, 2000)

For all those who cannot carry out the activities indicated above due to their health conditions, it is expected to constantly adopt an active lifestyle (e.g., prefer choices related to movement as to reach places of interest through walks rather than by means of transport and climbing stairs instead of using the elevator) by performing low intensity exercises and within the limits of one's ability: "*any type of movement is preferable to a sedentary lifestyle*" (Lee, Jackson, & Richardson, 2017). There are no contraindications if the activity is performed following specific criteria and indications and above all if the program is arranged and proposed in a different way for each individual subject.

The benefits that physical activity entails and how much it affects the overall well-being of the person have already been widely confirmed, but in recent years the practice of Home-Fitness is spreading to stay active. Just think of how today's market has paid particular attention to this area, creating a wide range of apps and platforms that allow you to train at home and, if you wish, to be followed or directed by experts, without the need for go out and go to the gym. Moreover, not only in certain cases it is a real necessity, but often the subjects prefer not to leave their home by choice. In this regard, the current COVID-19 pandemic should serve as an impetus for progress in this field, in fact "*it is urgent to develop innovative strategies to prevent functional decline among individuals at risk during periods of social detachment and quarantine, but many rural residents need this kind of services even under normal circumstances*". (Middleton, Simpson, Bettger, & Bowden, 2020.)

Speaking of Home-Fitness we refer to interventions "*aimed at strengthening the motor function that the non-use has reduced to a minimum. The primary goal is to increase body and motor awareness, creating training programs suited to one's lifestyle and physiological needs.*" (Federici & Dardanello, 2006) Therefore, linking ourselves to active aging, it is based on interventions focused on the individual and his abilities or "*the search for elements of well-being through activities related to a person's objectives, functional abilities and opportunities.*" (Rantanen & Saajanaho, 2018) Exercise carried out at home is an excellent tool to facilitate access to exercise and to avoid a sedentary lifestyle in the over 65, first of all, because home is considered the safest place where being able to better express oneself, away from comparison with others: the centre of the world for the elderly, who spend most of their time there (Barry, Heale, Pilon, & Lavoie, 2018), moreover, the awareness that is acquired leads to a better ability to reintroduce in society and participation, fighting "*isolation and loneliness which are particularly problematic aspects in old age.*" (Courtin & Knapp, 2015) "*Considering physical exercise as a real therapy and as a tool for reintegrating the person in their social context, gives it a double meaning*". (Federici & Palanca, 2019)

Objective

Deepen all aspects related to physical exercise carried out at home in the Third Age, through a systematic review of the scientific literature, investigating what are the findings ascertained to date and the evidence of greatest interest relating to it.

METHODS

The analysis was carried out on the major known scientific search engines, including PubMed, Google Scholar, SportDiscuss. The search was conducted based on the title, and abstracts were then analysed to exclude studies and reviews not appropriate to the topic.

Out of the total number of scientific articles viewed, only 31 (studies and reviews) met the required inclusion criteria, namely:

- Activities at home or partially at home;
- Excluding studies where the activities promoted were aimed at post-operative patients or subjects affected by serious pathologies, which did not allow them to live and carry out exercises independently;
- Free consultation of full-text;
- Studies concerning adults over 60/65;
- No limits have been set regarding gender, language, nationality and duration.

Data collected

Studies and related reviews all report a publication date after the year 2000, except numbers 26 and 31. The studies evaluate more than 10'000 subjects. Studies number 13, 20, 24 and 29 evaluate subjects aged ≥ 60, while the rest only look at ≥ 65.

From the review it emerged that 11 studies focus on physical activity planning proposed to frail or pre-frail subjects; 3 studies for sedentary elderly; 5 studies for healthy elderly people without particular pathologies; 5 for people with limitations or not completely limiting pathologies (osteoarthritis, low bone mineral density, damage to the lower body and cancer survivors), therefore, all adults at high risk of developing more serious pathologies or of losing functionality; the remaining 7 aimed at subjects with an ascertained clinical history of falls.

The studies are generally of long duration: most of 6/12 months; 10 3-month activity studies (12 weeks); only 3 exercise groups exceed 18 months (for both exercise and control group). Exercise sessions are required in 14 programs 3 times a week; at least 3 times in 2 articles; 2 studies once a week of 60 minutes; 7 work plans at least 2 weekly sessions; 4 searches at least 5-7 days of activity; finally, 1 study for once a month. 3 study groups perform training sessions in specialized facilities as well as exercise sessions at home. The duration of the sessions was highly variable, it was not possible to establish an optimal duration.

As concerning the nutritional / food aspect, 10 articles prepare a nutritional plan or advice on nutrition and good habits, while the remaining 21 do not take this component into consideration.

What emerges from the review, at the level of the objectives pursued, allows us to state that the attention of scholars in the sector, to date, is mainly focused on preventing and maintaining functionality, independence and autonomy. In fact, 12 studies aim to improve functional abilities, quality of life and performance in general; 12 articles have as their main purpose the study of falls (frequency, severity of injuries and fear of falling), associated with prevention and programs of strength and proprioception of the lower limbs; finally, 7 examine functional capacities, aiming to ascertain their tendency, following a targeted exercise program. The exercise proposals cover a wide range, in order to preserve functionality, the ability to independently carry out daily life activities and improve physical performance in general (balance, strength, aerobic capacity, mobility, posture, flexibility, strength hand grasp or ability to concentrate and neuro-motor stimulation). We note that no studio requires the purchase of equipment, in fact low-cost elastic bands, dumbbells or anklets are provided by the program managers. In most cases, the weight of the body or small tools is used, as required by the WHO guidelines.

The most used tool is the "*Otago Exercise Program*" (OEP), designed with the aim of reducing the number of falls, through strength exercises (especially of the lower limbs) and balance. This proposal was created to be usable in the over 65 age group at home. It involves 30 minutes of exercise 3 times a week with walking at least twice a week. We know that falls and related injuries are considered one of the biggest public health problems, also causing high social costs. (Martins, et al., 2018) Approximately 35% of people over 65 falls annually and this figure rises to 50% in those over 80, causing loss of confidence in their possibilities and loss of independence. (Thomas, Mackintosh, & Halbert, 2010) In addition to high social costs, 40% of all nursing home admissions have been found to be related to falls and instability. (Bjerk, Brovold, Skelton, & Bergland, 2017)

DISCUSSION

The review revealed interesting aspects regarding the over 65s and related to: adherence to exercise, choice of physical activity, study of frailty, prevention of falls and performance associated with functionality. The evidence confirms that active aging takes on extreme importance when we consider that the elderly seem to favour a better quality of life than longevity, that is, they prefer to live well even if for a shorter time. (Bjerk, Brovold, Skelton, & Bergland, 2017)

Systematic review suggest that home exercise interventions, which focus on progressively challenging balance and increasing strength, can reduce up to 42% of falls in those with a history of falls. (Gawler, et al., 2016) Despite the recognized benefits of physical activity, many still do not reach the WHO recommended amount of exercise target and poor adherence is related to both external factors (e.g. difficulty in locomotion and transport), (Brandão, Oliveira, Brandão, & et al., 2018) and fear. For example, Siegrist and colleagues state that concerns related to the fear of falling are found in 43% of the sample and 16% confirm that they reduce their usual activity to avoid risks: in the study, the subjects belonging to the intervention group, based on the prevention through physical exercise of 12 months, significantly reduced the fear of falling, compared to the group that received only the usual care provided by the National Health System. (Siegrist, et al., 2016) A further study adds that, following a fall prevention exercise program, the self-confidence of subjects who practiced in the exercise group improved significantly. (Iliffe, Kendrick, Morris, Griffin, & Haworth, 2015) These statements make us reflect on the importance of acting in a preventive manner, but above all through individualized and stimulating proposals, that is, which take into account personal needs and obtain a high degree of adherence, even in the long term. An article examined the percentage of completion of the programs once the study period ended, finding that: 84.7% of the participants in the intervention group committed themselves to continuing the lessons for the following 6 months, decreasing to 79, 1% at 12 months, obtaining statistically greater results than the control group. (Martins, et al., 2018) In this regard, with a view to long-term adherence, it should be considered to offer programs that consider both personal needs and the features of the program itself.

The evidence supports the thesis that the elderly chooses a certain physical activity, not only taking into account the benefits that it entails, but above all on the basis of particular characteristics, i.e., the distance from their home and the costs to be incurred, followed subsequently by the possibility of increase the ability to carry out daily life actions and reduce falls to a minimum. These statements highlight those strategies developed to engage seniors need to focus not only on health but on improving accessibility to exercise programs. (Franco, et al., 2015) Exercise that can be done at home or in the nearby, at no additional cost, is what most drives the elderly to undertake a physical activity program and follow it constantly over time. Various studies deal with physical exercise carried out in gyms or specialized centres, precisely because most of the programs are conducted in this type of facility, offering purely group activities. The most important consequence is found in the fact that the proposed protocols are less accessible to the elderly who, often, are not willing to go regularly to these centres. Therefore, the review of the studies allows us to affirm that home business is an excellent "*medicine*" that uses Home-Fitness as its main ingredient, and that often, good results can also be obtained by following a program of exercise at home proposed via video or DVD, at low cost. (McAuley, Wójcicki, & Gothe, 2013) (Fanning, et al., 2016)

Therefore, making physical activity easy and rewarding allows you to increase the number of subjects who practice it, placing a limit on the development of frailty. The latter, in fact, is a "*multifactorial geriatric syndrome, characterized by low physiological reserves and reduced resistance to stress events*", and many studies states that it is directly proportional to age. A clinical condition that has attracted particular attention in recent decades, also thanks to the dizzying growth of the elderly population and the prospect of life. (Pilotto, Custodero, & Maggi, 2020) Physical activity has been identified as a potential preventive strategy for both frailty in people aged 65 years and older. (Oliveira, et al., 2020) One study state that in frail or pre-frail subjects, an exercise program associated with an eating plan decreased the frailty score by 0.34 from baseline, the exercise program alone by 0.23, after 6 months. (Hsieh, Su, Chen, Kang, & Hu, 2019) Although minimal, these results are statistically significant in a population so sensitive to changes and improvements in physical and mental condition. The evidence reinforces the idea that the activity within the domestic walls is a highly recommended tool to prevent the onset of frailty and in some cases to reduce it, although it is not always possible to improve this condition at an advanced stage. We cite two studies that provide evidence that a prevention program, in frail elderly living at home, can delay functional decline, underlining however non-negligible aspects: "*despite the intervention, people with recognized severe frailty have had a worsening of disability over time*" (Gill, et al., 2002) and "*although exercise improves functional capacity, frailty has not been eliminated with training*". (Brown, Sinacore, Ehsani, & al, 2000) The findings indicate the need to prevent this condition, rather than wasting energy in modifying it at an advanced stage. In this context, it is considered essential to recognize the elderly predisposed to develop a condition of fragility and to intervene effectively, preventing possible risks and the loss of independence. As various scholars state in "*The American Journal of Medicine*", it is possible, thanks to prevention (Ng, et al., 2015), to identify people at risk and avoid hospitalization, institutionalization, functional dependence, or death. According to the literature, older people living in communities, in their home, always report better results than those living in institutions. (Haider, Grabovac, & Dorner, 2019).

Although frailty is a topic to focus attention on, in relation to the elderly we reiterate that the prevention of falls is equally important and is a source of study for many researchers who work in the protection of the health of the elderly and trust in movement as a means to get it. All the evidence collected allows us to state that a home exercise program based on improving the balance and strengthening of the lower limbs, proves to be an effective element in reducing the number of falls. A study reveals that following the strength and balance protocol, the difference in the rate of falls, between the exercise group and the usual care group, increased over time in favour of the exercise group, although it is unclear whether they are also valid on subjects with different criteria from those provided for in the inclusion. (Liu-Ambrose, Davis, & Best, 2019) Again, the various reviewed studies that dealt with this issue confirm that the average fall rate during the program period was significantly lower in the exercise groups than to control groups, leading to an improvement in the balance itself. A non-negligible positive consequence is the reduction in the number of fractures related to the fall. Finally, an article attempted to show that a fall prevention exercise program was correlated with bone mineral density, not achieving the desired results, explained by the fact that, perhaps, the exercises should have applied greater loads to the bone or exercise efforts of greater duration, confirming that the action of physical exercise in situations of osteopenia and osteoporosis is positive, if applied appropriately and not below the activation threshold. (Duckham, et al., 2015)

In addition to the concrete benefits shown, physical exercise carried out at home is confirmed as an excellent practice useful for optimizing the level of physical performance and consequently ensures a good residual autonomy. The evidence of greatest interest, relating to physical performance, can be found in the test scores present in each study. Obviously, the results cannot be compared, since they are data deriving from different use of measurement methods, proposed programs, clinical states and inclusion criteria. We can without considering the specific scores of each study, summarize the objective certainties obtained from the review, stating that physical exercise carried out at home in the elderly involves an increase of: muscle strength (in particular of the lower limbs), SPPB score that evaluates the functionality of the lower limbs, average walking speed and resistance, TUG score that evaluates mobility, static and dynamic balance, PPA score associated with decreased risk of falls, Barthel index score for functionality (ADL), flexibility, coordination, grip strength or less reduction compared to the control group.

CONCLUSION

The purpose of this work is to provide an overview of the critical issues and benefits related to exercise at home in the elderly, to understand the importance it has in this population. We can declare that there are many studies that examine this issue, but the main difficulty is certainly found in intertwining the results obtained.

Although it was not easy to evaluate the studies, due to the multiplicity of objectives, measurement and inclusion criteria, the evidence determines in depth the relationship between physical activity at home and over 65. Many studies conclude that, the elderly healthy people who regularly engage in moderate-intensity physical activity have a higher level of quality of life and well-being, both in the physical and mental domain, than less physically active subjects and give hope for an extended active life in old age. (Arkkukangas, Sundler, Söderlund, Eriksson, & Johansson, 2017)

Further data is needed to find the precise correlation between the results that can be obtained and the most effective mode of exercise in influencing a certain aspect, but we can assert that a multicomponent program that allows you to act in favour of the whole organism, is the solution to date, completer and more effective. What is reported by the scientific evidence and stated by the American College of Sports Medicine (ACSM): many reviews "*have demonstrated the superior effectiveness of multi-component exercise programs compared to mono-component exercise programs*", which include more than one type of exercise. (Freiberger, Kemmler, Siegrist, & Sieber, 2016)

To date, it is essential to improve accessibility to programs and increase long-term adherence. With a view to participation, two proposals are interesting: one allowed participants to take part in their treatment process, choosing together with the supervisor the exercises they wanted to perform, creating a change in the culture of assistance, (Mittaz Hager, et al., 2019) while the other providing for supervision by lay staff, or previously trained volunteers who followed the elderly unable to move from their homes, reducing both health costs and finding an alternative to the problem of lack of supervision. (Kapan, Winzer, & Haider, 2017) In this regard, we remind you that supervised training leads to greater benefits, in terms of performance and motivation, than unsupervised training.. (Lacroix, et al., 2016)

We conclude the review by being able to certify, following all the data collected, that physical activity carried out at home by elderly people is an excellent tool to hinder the onset of problems related to advancing age, bringing all the benefits returned previously. We summarize the results by reiterating that: it prevents and decreases the number of falls; avoids the loss of residual autonomy and the onset of a condition of fragility; improves physical performance, such as balance, strength, mobility, flexibility, aerobic capacity, etc.; it brings benefits on a cognitive level; finally, it allows you to increase your mood and general well-being. In addition, physical intervention, related to correct lifestyles, is able to reduce the self-reported rate of functional decline, compared to the results found in sedentary subjects.

Taking into account that the number of elderly people is constantly growing and that, even today, a large majority of them are sedentary or do not reach the amount of physical activity required by the world's major health organizations, not enjoying the related benefits, the Home-Fitness proves to be a complete, effective and accessible to everyone, even more so for the elderly.

AUTHOR CONTRIBUTIONS

Alessandro Capriotti: Quality control, article search, development of the final product. Valeria Patregnani: Articles search, manuscript preparation. Ario Federici: Project coordinator.

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SCIENTIFIC JOURNAL OF SPORT AND PERFORMANCE

ORIGINAL ARTICLE

Comparison of a new bioelectrical impedance device and its use in the assessment of body composition: A pilot study

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ABSTRACT

The objective of the present study is to determine the reliability of the measurements in the parameters of body composition of the Smart Performance measurement device and to compare the results with those produced by the InBody 270 device. Ten professional-level male athletes (mean weight = 58.4 kg ; height = 165.4 cm; BMI = 26.9 kg/m^2) were analysed. An experimental design of a single cohort was carried out. Participants were tested on two 5-point bioimpedance devices: In-Body 270 (Biospace, Seoul, Korea) and Smart Performance. Measurements were made in the after-noon (6:30 p.m. - 7:30 p.m.). The variables used were weight (kg), fat mass (kg), muscle mass (kg), body water (L), BMI (kg/m^2), protein and minerals. the Smart Performance Composition device presents a high degree of reliability for the analysis of body composition and its use at a recreation-al, sports and scientific level.
Keywords: Performance analysis of sport, Physical conditioning, Body composition, Impedance, Reliability.

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INTRODUCTION

The increase in sedentary behaviours, related to new technologies (television, mobile phones, tablets), represents one of the great problems in today's society (Becerra et al., 2013). That is why a sedentary lifestyle is considered a risk factor for health causing cardiovascular diseases, as well as obesity, diabetes and hypertension (Leiva et al., 2017). The practice of physical activity, from an early age, is one of the most important elements to achieve active and healthy lifestyles, preventing both obesity and overweight, in children, youth and adults (Mendoza-Muñoz et al., 2020) (Ortega et al., 2007).

In this way, body composition and nutritional status are understood as two key components that are associated with both health and sports performance (Larsen et al., 2021) (Campa et al., 2021). For this reason, in most sports, athletes can achieve great advantages in their modalities by changing their characteristics of mass or body composition, a fact by which athletes carefully adjust their training and nutritional habits according to the demands of his discipline (Sundgot-Borgen and Torstveit, 2010).

In this context, monitoring body composition has become crucial, and assessing it properly allows a more reliable assessment through anthropometry and bioelectrical impedance devices (Inbody 270). Specifically, the latter is used to calculate the total water in the body, fat mass and fat-free mass. Despite presenting less reliability and greater variability, it is compensated by the large number of people evaluated, simplicity, speed, safety and low application costs.(Costa et al., 2015).

In this way, the objective of this study is to determine the reliability of the measurements in the parameters of body composition of the Smart Performance measurement device and to compare the results with those produced by the InBody 270 device.

MATERIALS AND METHODS

Participants

10 professional-level male athletes (mean weight = 58.4 kg; height = 165.4 cm; BMI = 26.9 kg/m^2) and with a stable socio-economic profile were analysed.

All subjects were informed verbally and in writing of the procedure and purpose of this investigation and of the possible risks. The study was carried out in accordance with the Declaration of Helsinki and the protocol was approved by the Ethics Committee of the Technology-Based Company of the University of Alicante, and the Alicante Science Park (Kinetic Performance, S.L.)

Measures and procedures

An experimental design of a single cohort was carried out. Participants were tested on two 5-point bioimpedance devices: InBody 270 (Biospace, Seoul, Korea) and Smart Performance. Measurements were made in the afternoon (6:30 p.m. - 7:30 p.m.). The variables used were weight, Fat free mass (FFM), muscle mass, body water, BMI, protein and minerals. Participants did not consume alcohol 24 hours prior to measurements, did not engage in vigorous exercise 12 hours prior to measurements, did not eat or drink 3 hours prior to measurements, and urinated prior to measurements.

Statistical analysis

Descriptive (mean and standard deviation) and inferential tests were carried out using SPPS Statistics 18. We carried out the Kolmogorov–Smirnov test to analyse normality of data. The Mann–Whitney U-test with a

Bonferroni post hoc ($p < .01$) was carried out to analyse variables with non- parametric distributions. Variables with parametric distributions were analysed with Student's t-distribution ($p < .05$).

RESULTS

The results do not show significant differences between both devices (Table 1 and Figure 1).

Table 1. Statistical test for the comparison of body parameters.

Variables	Inbody270	Smart	Differences	Sig. (bilateral)
Height (kg)	69.2	70.2	1.03	.856
Fat (kg)	11.5	11.5	0.03	.991
Water (L)	42.2	43.1	0.83	.814
Fat free mass (kg)	32.4	33.2	0.79	.787
BMI (kg/m^2)	22	21.9	0.92	.920
Protein	11.4	11.7	0.75	.756
Minerals	4	3.9	0.81	.813

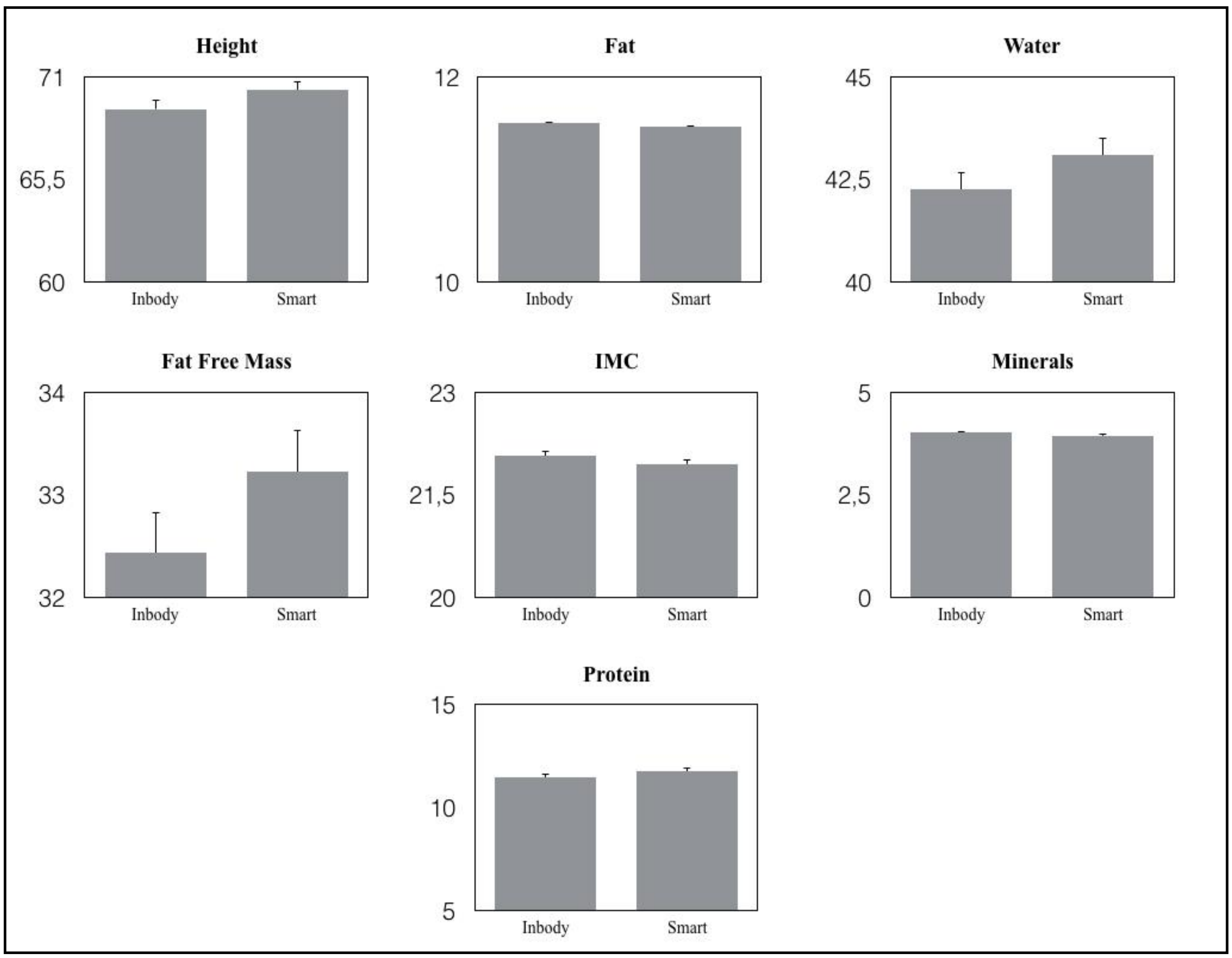

Figure 1. Results for the comparison of body parameters.

DISCUSSION AND CONCLUSION

The objective of this study is to determine the reliability of the measurements in the body composition parameters of the Smart Performance measurement device and to compare the results with those produced by the InBody 270 device.

Monitoring and evaluation of body composition can be decisive in sports performance (Malina, 2007). But the importance of body composition, and especially of bioelectrical impedance devices, is increasing in the health field. These kits are used in dialysis centres to help determine dry weight (Chamney et al., 2002). This makes comparisons between analysers necessary. InBody analysers have shown correlations of .94-.96 with the DEXA reference method (Karelis et al., 2013).

Fat Free Mass and body water are the main indicators in the physical performance of athletes (Toselli, 2021). The results obtained after comparing the body composition parameters of 10 athletes show values between both anthropometric analysis devices without significant differences. The differences in total water between both devices were 2% without reporting significant differences. Hydration is an important parameter in the health status of the population. In some studies, it has been reported that a reduction in body water between 3-5% can cause digestive problems and muscle spasms (Burke, 2007). The FFM values do not show percentage or significant differences. FFM values represent an essential indicator in sport. This has given rise to new productive models to determine excess fat mass and thus be used by trainers (Mascherini et al., 2019).

In conclusion, the Smart Performance Composition device presents a high degree of reliability for the analysis of body composition and its use at recreational, sports and scientific levels.

AUTHOR CONTRIBUTIONS

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

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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SCIENTIFIC JOURNAL OF SPORT AND PERFORMANCE

ORIGINAL ARTICLE

Motivational climate and attitudes towards doping among Kenyan endurance runners

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ABSTRACT

Doping is a worldwide problem that harms athletes' health and undermines the spirit of sport. Studies have shown that male athletes are more prone to doping than female athletes. Athletes with mastery climate have been associated with anti-doping attitudes, while those with performance climate have pro-doping attitudes. However, it is unclear whether motivational climate is equally important to attitude towards doping for males and females. Data were collected from 323 runners in Elgeyo-Marakwet County, Kenya, using cross-sectional survey design. Runners self-reported their motivational climate using Perceived Motivational Climate in Sport Questionnaire and attitudes towards doping using Performance Enhancement Attitude Scale. Correlational analysis indicated significant inverse relationship between mastery climate and doping attitude (rho = -.242; $p < .001$) and significant positive correlation between performance climate and doping attitude, (rho = .362; $p < .001$). Hierarchical regression analysis revealed performance and mastery climate were significant predictors of attitudes towards doping ($F (3, 319) = 28.24$, $p = .001$), and gender did not moderate the relations between motivational climate and doping attitudes ($\beta = -.028$, $p = .621$). MANOVA results showed male athletes were significantly lower in performance climate scores ($p = .045$) and non-significantly low in mastery climate scores ($p = .075$) and doping attitude scores ($p = .595$) than females. In conclusion, performance climate was associated with doping attitudes in females- but not in males. Therefore, policy frameworks that buttresses the aspects of mastery climate as opposed to performance climate in females is likely to promote anti-doping attitudes.
Keywords: Physical activity psycology, Gender differences, Mastery climate, Performance climate, Performance-enhancing substances, Achievement motivation.

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INTRODUCTION

Doping is a worldwide problem affecting both competitive athletes and non-competitive athletes (Donovan et al., 2002) and is a phenomenon that continues to evolve despite numerous negative consequences it poses to the health of the users, integrity and overall reputation of the sport (Barkoukis et al., 2013). Consequently, World Anti-Doping Agency (WADA) and National Anti-doping Agencies (NADO's) have developed and implemented various preventive and deterrence activities as part of efforts to fight this menace. Alongside these measures, studies have opined that identifying individual athletes and understanding situational factors that may positively or negatively influence athletes' doping intentions may assist in doping prevention (Lazuras et al., 2015; Petróczi et al., 2015). Similarly, Backhouse et al. (2012) opine that targeted anti-doping education on athletes about PES use and its associated risks will help mitigate harmful and disastrous consequences of doping and reduce its prevalence.

Research studies has shown that male athletes are more prone to doping than female athletes (Bloodworth et al., 2012; Devcic et al., 2018; Lata & Mondello, 2010; Peters et al., 2005; Petróczi, 2007; Sas-Nowosielski & Budzisz, 2018; Sas-Nowosielski & Swiatkowska, 2008; Soltanabadi et al., 2015). The motives for doping among male athletes is improvement in performance, the glamour associated with winning, and encouragement by coaches and peers (Peters et al., 2005; Petróczi,2007). On the other hand, female athletes have a reduced propensity to doping because they are more concerned about the harmful effects of doping, including emotions of humiliation and shame when caught doping compared to male athletes (Zaletel et al., 2015). However, there is scarcity of studies that have examined the contributions of gender and psychological constructs in predicting doping attitudes among Kenyan endurance runners.

Theoretical framework and previous studies

Achievement Goal Theory (AGT) (Nicholls, 1989) has been found to be useful in understanding certain psychological attributes associated with attitudes towards doping in sports (Allen et al., 2015; Donovan et al., 2002; Mwangi et al., 2019). The theory postulates that how individuals assess success and competence in achievement tasks (goal orientation) and how their social context is shaped (motivational climates) have an impact on motivated behaviour.

Motivational climate refers to salient goals and prominent values in the achievement context like sports (Ames, 1992). Motivational climate is categorized into mastery (or task) and performance (or ego) climate. Mastery climate is where success and competence are assessed through self-referenced perceptions, cooperative learning, equal treatment of each athlete by the coaches, and coaches fostering hard work and personal improvement of athletes, while performance climate is where competence and success are defined in reference to others, such as athletes outperforming others and winning, coaches favouring some athletes more than others, as well as intra-team rivalry, and punishing athletes when they make mistakes (Allen et al., 2015; Newton et al., 2000).

Motivational climate in sports consists of the external achievement expectations of Athlete Support Personnel (ASP), as perceived by athletes (Petróczi & Aidman, 2008). Therefore, athletes' interactions with ASP will influence how they perceive teamwork, competition, ability, effort, and outcomes in sport participation. Among the ASP, coaches have been reported to be the most influential in athletes' sport participation compared with other ASP (Bartholomew et al., 2010; Karjane & Hein, 2015; Stenling, 2016). For instance, coaches perform important leadership roles in motivating athletes achieve excellence by building competence, confidence, connection, and character using different types of knowledge, skills, and training (Stenling, 2016). In addition, coaches have been cited as critical influencers towards athletes' attitudes, intentions, and behaviours towards PES use in sports (Huybers & Mazanov, 2012).

Studies in Motivational climate have linked mastery climate with sportpersonship behaviours in sports, including respect for team officials, game rules, teammates, and opponents, while performance climate has been linked to unsportspersonlike behaviours such as taking shortcuts, cheating, injuring or disadvantaging other athletes (Kavussanu, 2007; Ntoumanis & Biddle, 1999; Sage & Kavussanu, 2008; Stanger et al., 2018; Selfriz et al., 1992). In this regard, McArdle and Duda (2002) found athletes with high-performance climate to be more prone to cheating in sports to increase their chances of winning than those with mastery climate. Similar studies in doping in sports have associated mastery climate to negative attitudes towards doping, whereas performance climate has been associated with positive attitudes towards doping (Moran, Guerin, Kirby, et al., 2008; Sage & Kavussanu, 2008). Therefore, fostering of coach motivational climate that buttresses the aspects of mastery climate as opposed to performance climate may aid in anti-doping efforts as mastery climate is protective to doping in sports (Allen et al., 2015; Sas-Nowosielski & Swiatkowska, 2008).

Attitudes towards doping have been used widely in determining doping prevalence in sports. For example, it is believed that athletes who have permissive attitudes towards PES use are more likely to engage in doping and PES use than athletes who have negative attitudes towards doping and PES use (Petróczi & Aidman, 2008; Petróczi et al., 2015). Studies have argued that prediction of athletes' attitudes in sports has been shown to predict the actual situation (Boit et al., 2012; Jalleh et al., 2014; Ntoumanis et al., 2014; Petróczi & Aidman, 2009). In a related study, Allen et al. (2015) submit that investigating athletes doping attitudes is critical in understanding the factors that influence the attitudes and thereby help in the formulation of policies at the individual and situational factors.

Studies have shown that knowledge on doping among athletes helps prevent the development of pro-doping attitudes but helps in the formation of anti-doping attitudes (Backhouse et al., 2007; Blank et al., 2014). Similarly, Fung and Yuan (2006) submit that coaches must prove their knowledge and ethically correct attitudes towards doping for coaches to function as role models. In addition, coaches must be more informed on the importance of creating an optimal motivational climate free from doping (Moran et al., 2008). This is also supported in (Allen et al., 2015; Bae et al., 2017), where coach-created motivational climate was found to have implications on athletes' task or ego goal orientation, and this orientation is in turn closely linked to pro-doping and anti-doping in sports.

Kenya is known globally as the powerhouse in distance running. Over the years, researchers have attempted to elucidate various factors that contribute to Kenya's extraordinary performances in distance running, including but not limited to associations between genetic predisposition (Scott & Pitsiladis, 2007); physiological and socio-cultural factors (Wilber & Pitsiladis, 2012); ethnicity (Tucker et al., 2015) and somatotypical characteristics (Eksterowicz et al., 2016). However, these extraordinary performances by Kenyan runners stand threatened with reports in the recent past revealing that Kenyan runners have been placed on the WADA compliance watch list after more than 40 athletes tested positive for PES use between the year 2011 and 2016 (Henning & Dimeo, 2018). Similar reports indicate that Kenyan endurance runners have produced more Adverse analytical findings (AAFs) on doping compared to all sports tested in Kenya between the year 2004 and 2018 (WADA, 2018). Indeed it was found that majority of Kenyan endurance runners had inadequate training in doping, with athletes support personnel (ASP) abetting and encouraging doping in Kenya (WADA, 2018). In a related study, Wambui and Waiya (2018) attributed doping by Kenyan endurance runners to drug abuse legislation, peer pressure, and money in athletics, including endorsements, sponsorships, and championship payments.

A review of previous studies found that performance climate positively predicts doping intentions and is associated with positive attitudes toward doping among athletes, whereas mastery climate negatively predicts doping intentions and is negatively associated with attitudes toward doping (Allen et al., 2015; Backhouse & McKenna, 2012; Bae et al., 2017; Mwangi et al., 2019; Sage & Kavussanu, 2008). Related studies on doping amongst Kenyan endurance runners have centered on the knowledge, attitudes, and practices of doping (Boit *et al*., 2012; Chebet,2014). However, none of the previous studies examined the effect of motivational climate on attitudes toward doping among Kenyan endurance runners. A study of this kind was considered necessary in order to improve our understanding of the relationships between motivational climate and attitudes toward doping. Gender differences may have a significant role in moderating the relationships between motivational climate and doping attitudes among Kenyan endurance runners, a population where little is known. The purpose of this study was to examine the moderating effect of gender in the relationship between motivational climate and attitudes towards doping among Kenyan endurance runners. The findings of this study provides new explanations in understanding the moderating effect of gender in the relationship between motivational climate and doping attitudes and thereby inform policy and actions.

METHODOLOGY

Study design, location and participants

A cross-sectional survey design was used in this study. Data was collected from Kenyan runners who were purposefully sampled from Elgeyo-Marakwet County (EMC), Kenya. The selection criteria focused on Kenyan endurance runners who had been training in EMC training camps for more than 6 months, were 14 years old or older, and had never failed doping control tests. Similarly, the target population included Kenyan endurance runners competing in races ranging from 800 meters to 10,000 meters, including track races, road races, cross-country races, and marathons in Elgeyo-Marakwet County, Kenya. Elgeyo-Marakwet County was purposefully chosen from among 47 counties in Kenya because it has a high concentration of endurance runners ranging from amateur to elite, hence priding herself as the "*home of champions*". In addition, Elgeyo-Marakwet County (EMC) has been cited as a golden region in terms of her contribution to World Athletics and, more specifically, Kenya's athletics success (Njehia, 2021).

A total sample of 323 endurance runners took part in the study, with 215 (66.6%) males and 108 (33.3%) females. The ages of the participants ranged between 14 and 45 years (M = 22.85; SD = 5.75) and runners' length of experience ranged between 8 months and 22 years (M = 5.68; SD = 4.43).

Data on study participants' demographics were stratified into categories for the purpose of statistical analysis. All participants were classified in two groups according to age: junior runners (aged 14 to 20 years) and senior runners (aged 20 years and above). Further participants were stratified in two groups according to gender: male runners (junior and senior male runners) and female runners (junior and senior female runners). The length of athletics running experience was also categorized in three categories as follows: short length running experience (one to seven years), medium-length running experience (8 to 14 years) and long length running experience (15 or more years).

Instrumentation

A self-report questionnaire with three sections was used for data collection. Section "*A*" contained items on athletes' demographic information such as age, gender and runner's length of athletic experience. Items in Section "*B*" on athletes' perceptions of coach motivational climate were assessed using an adapted version of the Perceived Motivational Climate in Sport Questionnaire (PMCSQ-2) (Newton et al., 2000). The scale consisted 33 items weighted on a 5-point Likert type scale ranging from (1) strongly disagree to (5) strongly agree that measured the various dimensions of mastery climate and performance climate. Items in Section "*C*" focused on athletes attitudes towards doping in sport. These were assessed using 17 items modified version of Performance Enhancement Attitude Scale (PEAS) (Petróczi & Aidman, 2009). The athletes responded to the 17 items weighted on a Likert type scale ranging from (1) strongly disagree to (5) strongly agree.

Reliability tests were done for the study instruments prior to data collection using the internal consistency technique. Acceptable internal reliability was established in advance for each measure used at .70 (Nunnally, 1978). Cronbach's Alpha reliability indices demonstrated acceptable reliability: PMCSQ-2 reported (.82) mastery climate and (.76) performance climate and PEAS scale reported (.89).

Ethical considerations

The study received ethical approval from Kenyatta University Ethical Review Board with reference approval number PKU/1074/11124. Before the start of data collection, participants were provided with informed consent that highlighted the nature of the study, the voluntary nature of their participation, the confidentiality of their responses, and their right to pull out of the study at any time without penalty. They were also encouraged to be honest in their responses and instructed not to write their actual names in the questionnaire. Informed consent was obtained from participants (except junior athletes aged between 14 and 18 years) who agreed to participate in the study and then given the questionnaire. For junior athletes (those between the ages of 14 years and 18 years), consent forms from both the coach and the athlete were obtained before the completion of the questionnaires.

Data analysis

Descriptive statistics (i.e., mean and standard deviation) were calculated to give summary values and bivariate correlations using Spearman's rho Correlation were calculated to examine the relationship between motivational climate and doping attitudes. Moderated Hierarchical regression analysis was used to determine whether the participant's gender moderated the relationship between Motivational climate (mastery and performance) and attitudes towards doping. Before conducting the analysis, assumptions for Moderated Hierarchical regression analysis that included normality, linearity, multi-collinearity and homogeneity of variance were executed on the questionnaires to determine if the sample distribution of the data met the assumptions (Tabachnick et al., 2007). The attitudes towards doping mean total score was entered as the dependent variable in the regression model. In step one, mastery climate and performance climate were entered as independent variables. In step two, three-way interactions terms (gender multiplied by mastery climate multiplied by performance climate) were entered. This procedure was consistent with the recommendations of Aiken et al. (1991). The scores of the independent variables were converted into z-scores to reduce the correlation between these predictors and their interaction term.

To determine gender differences in the levels of motivational climate and doping attitudes, one-way multivariate analyses of variance (MANOVA) was used. However, initial evaluation of the data showed that it violated normality by reporting Shapiro-Wilk test results of ($p < .001$, df = 323). Consequently, Pillai's trace was used in interpreting MANOVA results as recommended by (Field, 2018).

RESULTS

Table 1. Descriptive Statistics and Correlations for all study variables (N = 323).

Variable		Mastery Climate	Performance Climate	Doping Attitudes
Mastery Climate	*(rho)*	1	-.076	-.242**
	Sig. (2-tailed)		.171	.000
Performance Climate	*(rho)*	-.076	1	.362**
	Sig. (2-tailed)	.171		.000
Mean		4.17	2.88	2.32
Standard Deviation		.62	.62	.70

*Note. **. Correlation is significant at the .01 level (2-tailed).*

Descriptive statistics (i.e., mean, standard deviation and Spearman's rho Correlations) were calculated for all variables as shown in Table 1. Results indicate that the runners returned a mean and standard deviation of (4.17 ± .62) in mastery climate, performance climate (2.88 ± .62) and (2.32 ± .70) in attitudes towards doping. Spearman's rho Correlational analysis results indicated that performance climate is significantly and positively correlated to doping attitudes (*rho* = .362; $p < .001$), whereas mastery climate is significantly and negatively correlated with doping attitudes (*rho* = -.242; $p < .001$). However, the interaction between gender and motivational climate variables is uncorrelated (*rho* =.001; $p = .982$).

Table 2. Hierarchical Regression Analyses Predicting Attitudes towards doping (N = 323).

Regression	Variable	Beta	Df	Sig.	F	R	R^2	ΔR^2	sr^2	Sig. *for* ΔF
Step 1										
	Mastery Climate	-.20	(3,319)	.000	28.24		.21	.21	4.04	.000
	Performance Climate	.42	(3,319)	.000	28.24		.21	.21	18.00	.000
Step 2										
	Interaction	-.03	(4,318)	.621	.245	.46	.001	.001	.001	.621
	Mastery Climate	-.19	(4,318)	.001	21.20	.46	.001	.001	.03	.000
	Performance Climate	.42	(4,318)	.000	21.20	.46	.001	.001	.17	.000

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

Moderated hierarchical multiple regression analyses were used to test whether gender moderated the relationship between motivational climate and doping attitudes, as presented in Table 2. Results indicated that in Step 1 of the regression model, results were significant, F (3, 319) = 28.24, $p < .001$, revealing that motivational climate (mastery and performance) were significant predictors of attitudes towards doping. Motivational climate variables accounted for 21% of the variance in athletes' attitudes to doping. Examination of the individual beta weights indicated that mastery climate ($\beta = -.202$, $p < .001$) was a significant but negative predictor of attitudes towards doping, whereas performance climate ($\beta = .419$, $p < .001$) was a significant and positive predictor of attitudes towards doping.

Semi-partial correlations revealed that performance climate alone uniquely accounted for 17% of the variance explained in attitude towards doping. On the other hand, mastery climate negatively predicted doping attitudes and independent of the effects of performance climate accounted for 3% of the variance explained in attitudes towards doping.

In the second step of the model, when gender was the moderator, the interaction did not predict doping attitudes over and above what motivational climate variables were able to predict in step 1 with a very weak and small change in variance (R^2) and non-significant F change (β = -.028, p < .621). This finding showed that gender did not moderate the relations between motivational climate and doping attitudes (β = -.028, p < .621). This finding implies that the interaction of gender and motivational climate variables did not predict doping attitudes. However, the greatest predictor of doping attitudes in the second step remained performance climate (β = .424, p < .001) and the predictions made by mastery climate remained negative to doping attitudes (β = -.190, p < .001) and still stronger than the interaction (β = -.028, p < .621).

Table 3. Differences between Male and Female athletes on attitudes towards doping and perceived motivational climate (N = 323).

	Male	**Female**				
	M	*M*	*F*	*Df*	*Sig.*	η^2
Mastery Climate	4.13 ± .67	4.26 ± .54	3.184	(1,321)	.075	0.010
Performance Climate	2.83 ± .62	2.98 ± .62	4.033	(1,321)	.045	0.012
Doping Attitudes	2.30 ± .69	2.35 ± .73	.284	(1,321)	.595	0.001

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

One-way Multivariate analyses of variance (MANOVA) was used to determine gender differences in the levels of motivational climate and doping attitudes and the results are presented in Table 3. MANOVA results was not significant (Pillai's trace = .021, F = 2.325 (3,319), p < .075), η^2 = .021), indicating that there were no significant differences between males and females in the relationship between motivational climate and doping attitudes. Pillai's trace effect size (η^2 = .021) indicates that 2.1% of the variance in the dependent variables can be explained by gender.

Male athletes were significantly lower in performance climate scores compared with female athletes. Although male athletes had low scores in mastery motivational climate and attitude towards doping compared with female athletes, the same was not statistically significant. The effect sizes were small and weak for all the study variables; mastery climate (η^2 = .01), performance climate (η^2 = .01) and doping attitude (η^2 = .001). The effect size indicates that mastery climate, performance climate and doping attitudes are explained by little percentages, with mastery climate explaining 1%, performance climate 1.2% and doping attitudes 0.1% of the variance in the dependent variable (gender).

DISCUSSION

The purpose of this study was to examine the moderating effect of gender in the relationship between motivational climate and attitudes towards doping among Kenyan athletes. Studies have provided associations between motivational climate and doping attitudes (Allen et al., 2015; Bae et al., 2017; Hodge et al., 2013; Kavussanu, 2016; Moran et al., 2008; Stanger et al., 2018) and that gender also seems to play a key role (Mwangi et al., 2019; Peters Jr et al., 2005; Petróczi,2007; Zaletel et al., 2015). However, researchers have not examined the contribution of gender differences in explaining this relationship amongst Kenyan athletes. Therefore, it was critical to investigate the moderating role of gender in the relationships between motivational climate and attitudes towards doping to ensure that policy and anti-doping measures are gender-specific.

The results indicated that performance climate and mastery climate were associated with attitudes towards doping, with mastery climate showing a significant inverse relationship between mastery climate and doping attitude, suggesting that mastery climate was associated with attitudes towards anti-doping. On the other hand, performance climate and doping attitude indicated a significant positive relationship implying that performance climate was associated with attitudes towards pro-doping. Thus, the findings of the present study are in agreement with previous studies that have associated coach-created performance climate to positive attitudes towards doping and PES use in sports, while coach-created mastery climate is linked to negative attitudes towards doping in sports (Allen et al., 2015; Bae et al., 2017; Hodge et al., 2013; Kavussanu, 2016; Moran et al., 2008; Stanger et al., 2018). Further, the study showed performance climate and mastery climate were predictors of attitudes towards doping: mastery climate was a significant negative predictor of attitudes towards doping, whereas performance climate was a significant and positive predictor of attitudes towards doping.The findings of the current study corroborate previous studies in motivational climate where performance climate had been shown to positively predict doping intentions among the athletes, whereas mastery climate has been shown to negatively predict doping intentions (Sage & Kavussanu, 2008; Backhouse & McKenna, 2012; Allen *et al*., 2015; Bae *et al*., 2017; Mwangi et al., 2019). This finding could be explained in part by increased salient values between coaches and athletes in Kenyan training camps, as well as existing anti-doping deterrent and preventative initiatives conducted by ADAK, such as coach education and testing.

However, the results are in contrast to several previous studies in that gender was not significantly related to attitudes towards doping indicating that being either male or female did not significantly relate to one's attitudes towards doping (Petróczi,2007; Sas-Nowosielski & Swiatkowska,2008; Lata & Mondello,2010; Bloodworth et al., 2012; Soltanabadi, Tojari, & Esmaeili,2015; Devcic et al., 2018; Sas-Nowosielski & Budzisz,2018). The results further showed that gender did not moderate the relationship between motivational climate and doping attitudes, indicating that gender did not significantly influence the relationship between motivational climate and doping attitudes. This finding implied that the interaction of gender and motivational climate variables did not predict doping attitudes. Moreover, the results indicated no significant gender differences in doping attitude and mastery climate. These findings were surprising given the fact that previous studies has shown that male athletes were more likely to be prone to doping than female athletes (Bloodworth et al., 2012; Devcic et al., 2018; Lata & Mondello,2010; Petróczi,2007; Sas-Nowosielski & Budzisz,2018; Sas-Nowosielski & Swiatkowska,2008; Soltanabadi et al., 2015; Zaletel et al., 2015). This finding could be attributed to the fact that both male and female endurance runners in Kenya train in the same coaching environment, attend anti-doping seminars together and most of the time attend athletic competitions together.

Generally, Kenyan endurance runners in this study reported low attitudes towards doping, suggesting a low propensity to engage in doping among the Kenyan endurance runners. The general low scores on attitudes towards doping among the runners are consistent with previous studies (Allen et al., 2015; Morente-Sánchez et al., 2013; Mwangi et al., 2019; Petroczi & Aidman, 2009). In terms of gender, male endurance runners reported insignificant lower attitudes towards doping than female athletes, indicating that female athletes are more susceptible to doping and PES than their male counterparts. On the other hand, endurance runners in this study reported experiencing a high mastery climate in comparison to performance climate, indicating that coach created environment as perceived by endurance runners is the one typified by teamwork through cooperative learning, hard work, effort and personal development, and the runners feeling valued by having an important role in the team during practice and competitions. This finding demonstrates positive outcomes associated with mastery climate, which is supported in previous studies (Gencer & Öztürk, 2018; Mwangi et al., 2019; Selfriz et al., 1992). Therefore, a high mastery climate may protect Kenyan endurance runners from doping and PES use (Allen et al., 2015). In addition, female athletes portrayed stronger mastery and performance climate scores than male athletes, suggesting that female athletes assess their success and competencies in sports with reference to personal improvement, effort, teamwork, learning, winning and comparative performances.

The significant differences in performance climate between males and females indicate that female endurance runners in Kenya could easily be predisposed to doping compared to their male counterparts. The significance of low performance motivational climate scores in males compared with females indicate that male endurance runners in Kenya are at a lower "*risk*" of doping or using PES than female athletes. This could be attributed to the fact that most female athletes in Kenya are faced with two-fold challenges of being caregivers in their families and attending demanding athletic training and competitions. Like their male counterparts, females also face numerous psychosocial difficulties exacerbated by insufficient social acceptance, excessive reliance on close relatives, isolation, and a lack of mentorship and peer support. These challenges affect female athletes negatively in their athletic participation and performances.

Similarly, these challenges might provide challenging situations to some coaches leading to them condoning cheating and other unorthodox means in an effort to achieve success. This is buttressed in research examining doping in sport, where athletes' perceptions of coach performance motivational climate have been positively associated with attitudes towards doping (Allen et al., 2015; Mwangi et al., 2019). On average, athletes in this study reported experiencing less performance climate, which is a predictor of negative attitudes towards doping as indicated by Allen et al. (2015); thus, Kenyan endurance runners had more favourable attitudes towards anti-doping.

Strengths and limitations of the study

The current study has demonstrated significant relationships between motivational climate and attitudes towards doping among Kenyan endurance runners - a population where little is known about these relationships. In addition, gender differences that may moderate this relationship have also been elucidated. However, the study acknowledged certain limitations that should be considered in interpreting the findings of this study. For instance, the study is correlational, therefore, limiting the ability to tell if prior experience with PES and doping influenced present doping attitudes. Additionally, all data were gathered using minimal demographic information and a self-report questionnaire. As a result, we could not account for other confounding factors that could have contributed to doping attitudes.

CONCLUSIONS

Athletes in this study had a high mastery climate, which is associated with strong anti-doping attitudes, indicating that athletes in Kenya adhere to the tenets of sportspersonship. On the other hand, performance climate was the best predictor of doping attitudes amongst Kenyan athletes. In terms of gender differences, female athletes had a high performance climate than male athletes, which may mean that female athletes are at greater risk of PES use and doping than their male counterparts. The findings of the present study have implications in the way coaches nurture and interact with their athletes and the associated consequences of such actions. Therefore, creation of coaching climate that buttresses the aspects of mastery climate as opposed to performance climate in females is likely to promote anti-doping. Follow up studies are encouraged on the need to explore how the various psychological variables relate with actual doping behaviour. Similarly, a longitudinal study would be necessary to ascertain how attitudes evolve over time and experience.

AUTHOR CONTRIBUTIONS

All authors contributed to the study's conception, discussion and editing the manuscript. Data preparation, data collection and analysis were performed by Kevin Kiprotich Kipchumba.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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SCIENTIFIC JOURNAL OF SPORT AND PERFORMANCE

REVIEW ARTICLE

The math game: How motor activity and the use of own body can help in mathematical learning. Systematic review

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ABSTRACT

This work, by means of in-depth research and systematic review, aims to demonstrate whether there is a real and concrete correlation between motor education and the learning of logical-mathematical concepts in school-age children between 6 and 11 years. Initially, several protocols and interventions were selected using targeted electronic databases focusing research on the last ten years. Subsequently, the main theme was addressed, subdividing, and analysing the selected research based on four topics: literature, gesture, interdisciplinary and testing. In the theme "*literature*" two works have been compared concerning the learning of logical-mathematical concepts thanks to the introduction of the use of literature for children and manipulators. In "*gesture*" five works have been compared where mathematical learning took place through the association of gesture with explanation. The nine protocols signed "*interdisciplinary*" deal exclusively with this topic: how the movement and the use of the body intervene on mathematical learning. Finally, three data collection on the topic "*test*": how physical activity intervenes on the results of mathematical tests. Bibliographic research shows that pupils participate with interest in activities and there is no negative influence on this link, indeed a significant improvement was evident in most of the protocols and interventions. There is, however, the need to monitor research in the long term, to expand with a larger sample of children and use larger spaces.
Keywords: Mathematics, Movement, Physical education, Gesture.

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INTRODUCTION

In this article we will deal with the correlation between physical education and the learning of logical-mathematical concepts. We will try to evaluate if, indeed, there is a correlation between these two educationalbranches through the analysis of protocols inherent in the topic.

The functions of the mind have long been considered more important than those of the body. For this reason, physical education has long been devalued in schools, in favour of more academic time. Many studies over the past few years have been trying to overturn this conception, proving that children who practice greater physical activity show better academic performance. In support of this there are also many studies concerning the study of cognitive processes and body movements and how children experience physical and mental benefits when they participate in moments of physical activity. Pouw et al. (2014) study, through embodied theories, howcognitive processes are based on perception and body action. Paas and Sweller (2012) argue that it could be advantageous to use primary information, such as body movements, to help acquire secondary information and, therefore, help acquire knowledge. Many authors also questioned the influence of motor activity in developmental age from Rousseau and Pestalozzi to Piaget and Meinel. Concluding with the theories of intelligences by Sternberg and Gardner.

Thanks to Rousseau (1989) and his theories on the value of the body, numerous scholars have reconsidered the role of corporeality as a natural dimension of the person and as an effective tool for understanding reality. According to Rousseau, knowledge must be guided by observation, by personal experience, by the spontaneity and the usefulness that can derive from it. Pestalozzi (1933) also recognizes the importance of the child's bodily education in its natural progression. Subsequently Piaget (1966; 1967; 1973) correlates the development of the game with the mental one. He affirms that the game, being a spontaneous habitof infantile thought, should be used as the first tool for the study of the cognitive process of the child. A process that develops from an interaction with the surrounding reality through, also, practical knowledge. Meinel (1984), in connection with Piaget, finds in the movement the source of cognitive processes since, according to him, the first basic knowledge takes place through the senses. In the tripartite model of Sternberg's intelligences (1996) we can find the need to use different teaching strategies. According to him, intelligence is expressed through three different fundamental modalities: analytical, creative, and practical. Our school system only evaluates one: the analytical one. There is a need, therefore, to re-evaluate the other two intelligences, because only their combination contributes to the so-called "*successful intelligence*". It consists in the ability to achieve objectives by exploiting strengths, adaptation to the environment and by smoothing and correcting weaknesses. Connectingto Gardner (2002) we can conclude by saying that a school that wants to be inclusive, must consider the differentforms of intelligence and develop them all at the best, considering the different teaching strategies.

We can therefore say that the education of the mind and the body are closely connected. This is not only because already from the early stages of our growth the body acts as a mediator between us and the world, but also because we find important feedback in the regular movement for the correct psycho-physical development of the child. In fact, by educating the body we also favour the physical, mental, and social development of the child and through gestures we construct increasingly complex body patterns and then place them alongside the word, enriching thought (Federici et al., 2008). The body is, therefore, the means by which each individual experiences the environment. We could say that adequate movement activities, controlled and organized in an organic program can interact with educational processes, thus helping children to approach them.To accomplish this, there is a need to move from traditional to more active teaching. The maximum theoretical of this method is Dewey (1968; 1969) that proposes an active school where the child can develop and cultivate activities and interests favouring, also, his natural instinct to do and to act. Learning by doing is the conceptual assumption underlying this methodology. Citing the Italian national indications (Ministero dell'Istruzione, dell'Università e della Ricerca, 2012) we can read how mathematical knowledge closely links making and thinking and to do this the laboratory is important. Laboratory understood as a moment in which the student is active, formulates hypotheses, controls the consequences, designs, and experiments. So, we note that the teaching of mathematics must not be reduced to simple verbal learning, but must be linked to a didactic of doing, of experimenting, leading children to solve real and daily problems of life. The objectives of teaching mathematics in primary schools can therefore be linked to some objectives related to physical education. Both teaching subjects, in fact, propose to prepare children for real life outside the school, learning to relate to each other and the rules to be followed and both help them also to develop their own personality.

In conclusion, the initial hypothesis of this work is to demonstrate how physical activity can help to make many mathematical concepts more understandable. Being able to stimulate the use of motor activities in the learning of logical-mathematical concepts could be advantageous for several reasons: it could help children learn mathematics with more motivation and participation, making this knowledge less hostile, and, moreover, it would help to combat data on sedentary and childhood obesity. The purpose of this article is to evaluate the selected research that examine, precisely, the correlation between physical education and logical-mathematical learning in the developmental age, specifically between 6 and 11 years. In doing so, we want to evaluate the pros and cons of this interdisciplinary relationship, trying to help develop guidelines or future research ideas on this specific topic.

MATERIAL AND METHODS

In support of this research, various articles and research reports have been viewed. Examine the link and interdisciplinary between physical education and the learning of logical mathematical concepts.

Inclusion criteria

The main inclusion criteria concerned the age of the children and the date of publication of the studies. Samples of children between the ages of 6 and 11 have been included, and articles published from 2009 to 2018 have been selected, with one exception. To improve the quality of the research, the protocols were also selected on the basis of the evaluation tests carried out. It was decided to evaluate the interventions that had performed pre and post-tests with qualitatively better. Gradually, protocols were selected that had carried out at least one control test and finally included some interesting protocols related to operations performed without any testing. Unfortunately, it was not possible to include only protocols with large samples and with the mandatory use of pre and post-tests, but this also allowed the evaluation of the importance or not of these aspects. Some articles, thanks to this choice, have been included for the interest and the research ideas they could offer.

Research strategy

Initially, the bibliographic electronic research databases were selected: Eric, ResearchGate, Sport Discuss and Urbis. Almost all the protocols come from the first engine used, namely Eric, since a meticulous search was carried out and many of the selected articles were then found also in the others. Some protocols have been selected through the bibliography of the protocols examined and found thanks to ResearchGate.

The main keywords used for the selection of studies were physical education, motor skills, mathematics, movement, and body. These keywords have been combined with each other in research, even with others as narrative, elementary, developmental age.

For each article found a first selection has been made through abstracts. Some interventions were included in the research, as already mentioned, even if the sample of children was restricted. At this time, a first summary table has been created, generated by a first reading of the fundamental parts of the document. Then, forchosen ones the table was completed in all its entries. Beyond the table a document was created with title, authors, magazine, and a summary of the various selected protocols managed by topic, namely: the use of children's literature and manipulators, the gesture, interdisciplinary between physical education and mathematicsand influence of physical activity on mathematical tests. It was decided to make this subdivision to be able to better view and compare the protocols between them and have a better view of the whole.

Data analysis

The data were extracted in a table initially divided into year and country, title, authors, number of children, activity, duration of experiment, results, magazine, search engine. Subsequently the analysis of theprotocols was carried out in four sub-categories already mentioned above. The first comparisons were made,therefore, by topic, looking at how the various interventions were carried out, considering their duration, thenumber of children, the use of pre and post-tests and the results. Only subsequently these data were further compared with each other to find similarities or differences.

Evaluation risks

The risk of assessment was assessed based on the data collection for each protocol under review. Studies with pre and post-test evaluations were evaluated with less risk, followed by pre or post-test interventions. A subsequent risk assessment is that each study asks for parental consent to include children in the tests and someone may not have joined for several reasons. For this reason, the assessment may have been influenced byinherent self-assessment biases.

RESULTS

After a careful analysis,19 articles met the inclusion criteria and were divided into sub-topics: 2 relating to children's literature and the use of manipulators, 5 concerning the use of the gesture, 9 inherent in the interdisciplinary nature of physical education and mathematics and 3 related to the influence of physical activityon mathematical tests.

The articles were published in a period of 10 years: from 2009 to 2019, except for an article published in 2007. The duration of the interventions varies from a single lesson up to 3 years. Also, the number of children for each sample differs considerably and varies from a single class up to 311. Articles from 5 countries have been included. Most of them took place in the USA, but there are also articles from Turkey, Australia, Holland,and Serbia.

Overall, we can say that positive results have been found regarding the link between physical education and mathematics in all the areas examined, but some studies should be improved and can only be used as a basisfor future research to have more scientific data collection. Furthermore, many topics are still to be explored. It was difficult, for example, to find interventions performed directly in the gym, related to children's literature, or performed on large samples. In none of the protocols examined were damages to logical-mathematical learning due to an increase in physical activity.

Below we analyse the results divided by topic, together with the summary tables of the protocols under consideration.

The use of children's literature and manipulators

Unfortunately, the protocols that bind these three main features are few and all are performed without pre and post-tests and on small samples. It was possible to select only two, described in Table 1, for interest and not for their scientific value. This selection is intended to be an incipit to further encourage this argument with morespecific targeted interventions and better data collection.

Table 1. Protocols of the topic literature.

Title	Bringing stories to life: integrating literature and math manipulatives	Sharing beans with friends
Year, Country	2018, USA	2013, USA
Authors	Larson L. C., Rumsey C.	Bell C. V.
Number of children, their age	A classroom, 7/8 years	Two classes, 6/8 years
Activity	Teaching of mathematics through the use of literature and manipulation	Mathematical activity on the division carried out on a story, followed by an interview with 4 children
Setting, duration	Classroom, 1 lesson	Classroom, 3 days
Results	The children showed interest	The children showed interest and participation
Magazine	Reading Teacher, v71 n5 p589-596	Teaching Children Mathematics, v20 n4 p238-244
Search engine	Eric	Eric

Both studies take place in the USA on an indefinite number of children between 6 and 8 years and have the duration of a single lesson or three interventions. The data were collected based on observations during theintervention and showed that the lessons were very engaging and motivating. This, as mentioned, can be a starting point for future research: expanding the examined sample, adding pre and post-tests and trying to increase the intervention time as well.

The gesture

In this section 5 protocols have been selected one of which is carried out in the Holland and all the others in the USA. The sample of children for intervention varies from 50 to 118 and they have between 6 and 10 yearsold. All interventions are individual between the child and the examiner and do not take place in a real class situation. Most of them have performed both pre and post-tests. This is a significant point of the real concreteness of the results, even if the effects of the same interventions carried out in the class group are not known.

Two studies where students carry out the action, described in Table 2, have shown the importance of the meaning of gestures, the importance that they are targeted in the learning examined. So, it does not matter that the gesture is explained, but that it is meaningful for children.

This was also highlighted by the other two interventions, described in Table 3, regardless of whether the children onlyvisualized the gesture or reproduced it.

Table 2. Two protocols of the topic "*gesture*" where students carry out the action.

Title	**Moving to Learn: How Guiding the Hands Can Set the Stage for Learning**	**Gesturing Gives Children New Ideas About Math**
Year, Country	2015, USA	2009, USA
Authors	Brooks N., Goldin-Meadow S.	Goldin-Meadow S., Cook S. W., Mitchell Z. A.
Number of children, their age	58 children, 8/10 years	128 children, 8/10 years
Activity	Investigate whether driving children's movements influences mathematical learning	Explore the mechanism by which gestures play a role in the mathematical learning of equivalence
Setting, duration	Classroom, 3 phases of intervention	Classroom, 2 lessons
Results	The activity of the movement has influenced the implicit understanding of the problems	The gesture can affect learning
Magazine	Cognitive Science A Multidisciplinary Journal, v40 n7 p1831-1849	Psychological Science, v20 n3 p267-272
Search engine	ResearchGate	ResearchGate

Table 3. Two protocols of the topic "*gesture*" where student observe the gesture.

Title	**Gesture Helps Learners Learn, but Not Merely by Guiding Their Visual Attention**	**Better together: Simultaneous presentation of speech and gesture in math instruction supports generalization and retention**
Year, Country	2018, USA	2017, USA
Authors	Wakefield E., Novack M. A., Congdon E. L., Franconeri S., Goldin-Meadow S.	Congdon E. L., Novack M. A., Brooks N., Hemani-Lopez N., O'Keefe L., Goldin-Meadow S.
Number of children, their age	50 children, 8/10 years	72 children, 8/9 years
Activity	Investigate if the gesture could influence the visual-motor attention during the learning of equivalence problems by watching some videos	Investigate the importance of the relationship between the gesture and what is said during mathematical learning
Setting, duration	Classroom, 2 interventions	Classroom, 3 days
Results	There is a relationship between gesture and visual attention when the gesture predicts learning	It seems to have benefits on learning
Magazine	Developmental Science, v21 n6	Learning and Instruction, v50 p65-74
Search engine	Eric	ResearchGate

A protocol, described in Table 4, wanted to ascertain whether there were significant improvements also throughthe self-observation of one's own gestures, but this was not observed.

Table 4. Protocol of the topic "*gesture*" with self-observation.

Title	**Watch your stepchildren! Learning two-digit numbers through mirror-based observation of self-initiated body movements.**
Year, Country	2015, Holland
Authors	Ruiter M., Loyens S., Paas F.
Number of children, their age	118 children, 6/7 years
Activity	It investigates how gestures influence mathematical learning.
Setting, duration	Gym and classroom, 2 interventions
Results	Improvements of groups in situations of movement, but there were no significant results inherent in self-observation
Magazine	Educational Psychology Review, v27 n3 p457-474
Search engine	Eric

Interdisciplinary between physical education and mathematics

Many experts think that the movement and use of the body can bridge the gap between mathematical learning and everyday life. To verify this thesis, 9 protocols have been selected mainly from the USA, but also from Australia, Turkey, and Serbia. Almost all the interventions, unfortunately, were carried out entirely in the classroom, only 3 of them were being held in the gym or even in the schoolyard, described in Table 5. The studies carried out entirely in the classroom can be seen in Table 6.

Table 5. Protocols of the topic "*interdisciplinary*" carried out in gym or schoolyard.

Title	**"*Learning Math on the Move*": Effectiveness of a Combined Numeracy and Physical Activity Program for Primary School Children**	**Becoming One in the Fitness Segment: Physical Education and Mathematics**	**The Effects of Integrating Mathematics into the Physical Education Setting**
Year, Country	2018, Australia	2018, USA	2015, USA
Authors	Vetter M., O'Connor H., O'Dwyer N., Orr R.	Griffo J. M., Kulinna P., Hicks L., Pangrazi C.	Thompson S., Robertson J.
Number of children, their age	88 children, 9/10 years	55 children, 8/10 years	91 children, 6/7 years
Activity	Multiplication teaching with an active learning approach linked to motor activities in comparison with a traditional approach	Through the KIA format, mathematics implement in physical education	Integrate mathematical learning in a context of physical education
Setting, duration	Classroom and schoolyard, 20 weeks	Gym, 4 weeks	Gym, 5 weeks
Results	No significant improvement detected	The students responded positively to this teaching model	Integration has improved the learning environment and improved mathematical performance
Magazine	Journal of Physical Activity and Health, v15 p492-498	Physical Educator, v75 n4 p647-660	Masters of Arts in Education Action Research Papers, St. Catherine University, Saint Paul, Minnesota
Search engine	Eric	Eric	ResearchGate

Table 6. Protocols of the topic "*interdisciplinary*" carried out in the classroom.

Title	**Developmental relations among motor and cognitive processes and mathematics skills**	**Purposeful Movement: the integration of Physical Activity into a Mathematics Unit**	**Walk the number line – An embodied training of numerical concepts**
Year, Country	2018, USA	2017, Turkey.	2013, USA.
Authors	Kim H., Duran C. A. K., Cameron E. C., Grissmer D.	Snyder K., Dinkel D., Schaffer C., Hiveley S., Colpitts A.	Linka T., Moellerb K., Huberb S., Fischera U., Nuerka H. C.
Number of children, their age	256 children, 5/6 years	24 children, 8/9 years.	33 children, 6/7 years.
Activity	Explore transactional associations among visual-motor integration, attention, motor coordination and mathematical skills	Integration of motor activities with mathematical learning trying to improve both aspects.	Intervention aimed at the spatial representation of numbers.
Setting, duration	Classroom, 3 years	Classroom, 1 lesson and 2 moment of data collection.	Classroom, not specified.
Results	They showed mutual correlation	There was an improvement in motor activity, but no significant improvement inherent in mathematical learning.	Integration has improved the learning environment and improved mathematical performance.
Magazine	Child Development, v89, n1, p476-494	International Journal of Research in Education and Science, v3 n1 p75-87.	Trends in Neuroscience and Education, v2 p74–84.
Search engine	ResearchGate	Eric.	ResearchGate
Title	**Mathematical terms in physical education curriculum**	**Student Academic Performance Outcomes of a Classroom Physical Activity Intervention: A Pilot Study**	**Students' voices and learning experiences in an integrated unit**
Year, Country	2012, Serbia	2012, USA	2011, USA
Authors	Milanovic S., Markovic Z., Ignjatovic A.	Erwin H., Fedewa A., Ahn S.	Chena W., Coneb T. P., Coneb S. L.
Number of children, their age	30 children, 7/8 years	29 children, 8/9 years	35 children, 7/8 years
Activity	To help students solve mathematical problems through physical education	Realization of pauses of significant motor activity, inherent in mathematical learning	Interdisciplinary didactic unit between physical education and mathematics
Setting, duration	Classroom, 1 lesson	Classroom, 20 weeks	Classroom, 4 lessons
Results	Most students appreciated the combination of these two disciplines	Positive but not significant effects on mathematical learning	It demonstrates the effectiveness of this educational combination
Magazine	Research in Kinesiology, v40 i2 p263-277	International Electronic Journal of Elementary Education, v4 i3 p473-487	Physical Education & Sport Pedagogy, v16 i1 p49-65
Search engine	Sport Discuss.	Eric	Sport Discuss

The age of the children is between 5 and 10 years and the number of them participating in the intervention variesfrom 24 to 256. The duration of these interventions is varied: some last a few lessons, others weeks or even 3 years. These elements are, perhaps, the most significant interventions of the research. Overall, most of the studies showed a significant improvement in logical-mathematical performance after the implementation of motor activities. Even the latter, in general, have improved, but this has not been demonstrated by all the protocols examined. Only three studies did not find significant improvements regarding logical-mathematical learning.

Influence of physical activity on mathematical tests

After analysing various protocols, 3 were selected, described in Table 7. All the studies were carried out in the USA and are performed on samples of numerous children between the ages 8 and 11 years. Although they implement 3 different data collection strategies, all have found that an increase in timespent on physical activity or better motor performance positively affects the results of mathematical tests.

Table 7. Protocols of the topic "*test*".

Title	**Childhood Fitness and Academic Performance: An Investigation into the Effect of Aerobic Capacity on Academic Test Scores**	**Physical Fitness and Academic Achievement in Elementary School Children.**	**Physical Education and Its Effect on Elementary Testing Results.**
Year, Country	2014, USA	2009, USA	2007, USA
Authors	Hobbs M.	Eveland-Sayers B. M., Farley R. S., Fuller D. K., Morgan D. W., Caputo J. L.	Tremarche P. V., Robinson E. M., Graham L. B.
Number of children, their age	96 children, 10/11 years	134 children, 8/11 years	311 children, 9/10 years
Activity	Quantum study of the physical conditions of students and the results of school learning tests	Objectively examine the relationship between physical health and academic performance	Verifies the impact of the hours dedicated to motor education
Setting, duration	Classroom, only data collection	Gym and classroom, 3 weeks	School, 2 months
Results	Having a better level of aerobic health has had a positive impact on academic performance	Several correlations have been identified between physical performance and findings in mathematics tests	Students who received more hours of physical education obtained better scores in school learning assessment tests
Magazine	https://files.eric.ed.gov/fulltext/ED560160.pdf	Journal Of Physical Activity & Health, v6 i1 p99-104	Physical Educator, v64 n2 p58-64
Search engine	Eric	Urbis	Eric

DISCUSSION

This work is a bibliographic search for data collection and the most significant interventions concerning the link between motor activity and mathematics in children aged between 6 and 11 years. Specifically, it wants to be a starting point for the development of future interventions, to understand what to improve and what to focus on. For this reason, topics that do not fully meet all the inclusive starting criteria have also been included.

We found evidence in favour of the interdisciplinary between physical education and logical-mathematical learning. Some studies, however, should be carried out on larger samples and should also include students with difficulties in mathematics. As already noted, it would be necessary to expand the studies that link these two disciplines with narration and try to carry out more interventions in the gym.

Children's literature is important because it supports active involvement and is rich in social interactions, helping to provide even greater enthusiasm and motivation in children. According to Golden (2012) it, in fact, provides important, meaningful contexts during the learning of logical-mathematical concepts. By linking these two concepts to the use of manipulators, you can help children bring everything to an increasingly real and concrete level. In fact, they move learning beyond traditional passive practices towards a more active learning plan that aims to incorporate creativity, critical thinking, and ideas together. In fact, when students use manipulators, they are more interested, active, and engaged in the lesson. Therefore, they can help them connect the various concepts and integrate them with their previous knowledge and skills, helping them to explore their ideas.

Even focused gesture can help in this when used in educational contexts. Various experimental studies have found that children are more likely to learn from instruction that includes speech and significant gestures than from speeches alone (Ping and Goldin-Meadow, 2008; Signer and Goldin-Meadow, 2005; Valenzeno et al.,2003). But most research related to gesture and learning, however, focuses on education based on them and not on their use by children. Even in this work it was difficult to find and select the interventions.

For these reasons, these two sections were introduced between the arguments to evaluate the results of current research and verify if these advantages exist. Though, several studies, especially those on the gesture, were carried out individually and not in a real classroom context, this aspect should also be more developed.

Studies in this regard are increasing considerably on the subject, but there is still a need for more interventions to better understand this link. This research, for these reasons, has tried to bring to the vision thebest interventions carried out over the last few years both in terms of reliability and future interests.

CONCLUSION

Not all the reported data have a scientific rigor, but thanks to the analysis of the examined studies, we can say that an improvement was found both in the educational context and in the performances examined in the various interventions, both as regards the learning of logical-mathematical concepts and motor performance.

However, further studies are therefore needed to address these issues in a more scientific and meticulous datacollection context.

The interest of scholars is growing over the past few years towards this field and this could lead to further news on the subject in the years to come, to confirm this we can note that half of the interventions examined are carried out over the last years.

AUTHOR CONTRIBUTIONS

Manuela Valentini: scientific coordinator. Arianna Anelli: bibliographic research. Ario Federici: project coordinator. Equally distributed contribution.

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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

Non-invasive approach for the assessment of oxidative stress after intense judo activities

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ABSTRACT

Oxidative stress induced by physical activity has received much attention in recent years due to numerous research papers. Physical activities (aerobic, anaerobic and resistance training) lead to an increased production of highly oxidative substances (RONS, both oxygen and nitrogen containing radicals) and this effect depends mainly on the intensity of muscular work. The combination of anaerobic and aerobic energy systems, as seen in judoka, provides more pathways for free radical production than single exercise training. The purpose of this study was to investigate the use of a non-invasive, simple battery to assess and monitor oxidative stress in judo athletes to better characterize the oxidative stress response to anaerobic and aerobic incremental exercise typical of the judo discipline.
Keywords: Performance analysis of sport, Physical conditioning, Young judoka, Non-invasive sampling, ROS, MDA, Cortisol, Bilirubin.

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INTRODUCTION

Martial arts are physical, mental and spiritual practices, and judo is one of the specialties that require high technical skills and the fastest possible execution of the most important technical actions (Franchini *et al.*, 2011; Thomas *et al.*, 1989). Judo is also described as a multi-joint, high-intensity movement discipline where specific throwing techniques require good physical fitness (Franchini *et al.*, 2003). This dynamic, physically demanding sport requires a high level of physical conditioning and strength to be successful and to compensate for fatigue. Many authors refer to judo as an explosive strength sport that requires tremendous reserves of anaerobic power and capacity, but also operates with a well-developed aerobic system (Callister *et al.*, 1990; Thomas *et al.*, 1989; Ray, 1992).

Considering that a match can last a few seconds or up to eight minutes (5 minutes of play + 3 minutes of golden score), the typical time structure in the match is 20-30 seconds of activity with a 5-10 second pause, during which athletes spend approximately 51% of the time trying to execute a good grip, resulting in a high physiological load on the upper body. Movement time analysis (Sterkowicz, Blecharz and Lech, 2000) has shown that judo competitions are characterized by maximal efforts (100% VO_2) of 10-15 seconds interspersed with recovery periods of submaximal force that include pushing, pulling and lifting. Therefore, both the aerobic and anaerobic metabolic systems are alternately stimulated.

The short burst of energy is provided mainly by anaerobic metabolism, but intermittent muscle work and recovery periods are maintained by aerobic cellular processes (Radovanovic *et al.*, 2009).

It is well described that optimal performance and strength are correlated with the oxidative status of the body. Many studies (Brancaccio et al., 2020; Finaud, Lac and Filaire, 2006; Castrogiovanni and Imbesi, 2012; Nikolaidis *et al.*, 2012; Fisher-Wellman and Bloomer, 2009; Teixeira *et al.*, 2009) have now confirmed that contracting muscles produce radicals and other reactive oxygen/nitrogen species (ROS /RNS) and the relation between oxidative stress and sport is proportional to the intensity of physical exercise. Furthermore, it is now well established that the level of reactive species in skeletal muscle plays a critical role in regulating force production. In fact, there is an optimal redox balance in muscle where the contractile apparatus has the highest force production. In combination with other factors such as growth factors and chemokines, ROS is involved in a cascade of events leading to muscle regeneration and repair (Barbieri and Sestili, 2012), but the local persistence of ROS can lead to muscle damage from oxidative injury. Similarly, ROS, produced during exercise, promotes the formation of new mitochondria, but at higher and persistent concentrations they could attack mitochondria and mitochondrial DNA (mtDNA) and block myogenic differentiation.

The different capacities of ROS are part of the intriguing theory of hormesis (Radak, Chung and Goto, 2008). When present at low concentrations, these reactive species are necessary for basic processes in the cellular environment, but when their concentration exceeds a threshold, deleterious effects on DNA, proteins, and lipids can occur. The body's adaptation to a different workout does not occur without fatigue, but the degree of fatigue is important because extreme fatigue can lead to significant cellular changes. The effect of ROS on muscle force production changes when a high ROS concentration occurs, and the result is a decrease in strength.

The ability of the human organism to prevent or counteract oxidative damage can be analyzed with a series of integrated biomarkers, indicators of normal and pathological biochemical processes. Several in vitro markers of oxidative stress exist, but most are of limited value in vivo because they lack sensitivity and/or specificity or require invasive methods and expensive equipment. However, it is desirable that these assays are non-invasive sensitivity tests for the effects of exercise on the human body.

The aim of this work is to apply a simple test battery in judo athletes to investigate the oxidative status response to a sports competition and to compare it with that shown in non-competitive effort and in non-effort situations. Each athlete is studied during a microcycle of training/competition, and the reference status is the same athlete at rest. The main objective of the work is to study how judo athletes react to stress experienced in training and competition situations analyzing the optimal redox state of athletes to reduce skeletal muscle damage and be successful in competition.

MATERIAL AND METHODS

Reagents

Bilirubin (BR) (Lot. 031M1429V #B4126; Sigma-Aldrich), dibasic sodium phosphate (Na_2HPO_4), monobasic sodium phosphate ($NaH_2PO_4 \cdot H_2O$), sodium chloride (NaCl), hydrochloric acid (HCl), pycric acid ($C_6H_2(NO_2)_3OH$), sodium hydroxide (NaOH), sodium tetraborate decahydrat ($Na_2B_4O_7 \cdot 10H_2O$), sodium acetate trihydrate ($CH_3COONa \cdot 3H_2O$), glacial acetic acid (CH_3CO_2H), 2,4,6-tripyridyl-S-triazine (TPTZ), Iron(III) chloride anhydrous ($FeCl_3$), thiobarbituric acid (TBA), cortisol standard, dichloromethane (CH_2Cl_2), acetonitrile (CH_3CN), bovine serum albumin fraction V (BSA, A-7906), β-glucuronidase (G8420-25KU) were all analytical grade and was purchased from Sigma-Aldrich. HUG was synthesized and purified as described (Bandiera et al., 2020). Ultrapure water milliQ was used to prepare each solution.

Subjects

Two male judoka who train at the same judo club and compete at the national level volunteered for this study. The physical characteristics of the participants are shown in Table 1. The two athletes were recruited based on their age and judo experience with a frequency of four training sessions (1.5 hours) per week. One of these two athletes was observed one year after the initial observation, during an intense period of competition.

The parents of the participants gave written informed consent to participate in the study, which was conducted according to the protocol approved by the Ethics Committee of the University of Trieste.

Table 1. Subjects physical characteristics.

	Age (years)	Judo practice (year)	Hight (m)	Weight (kg)	Body Mass Index ($kg \cdot m^{-2}$)
Athlete 1	16	9	1.90	116	32.1
Athlete 2	16	9	1.87	89	25.4

Participants guarantee:

1. Good health;
2. No metabolic disorders (diabetes, cardiovascular, hepatic, gastrointestinal or renal disease);
3. No pharmacological treatment or antibiotic;
4. No supplemental vitamin and antioxidants;
5. No smoking;
6. Equilibrate diet;
7. No recent surgery or blood transfusion.

Sampling protocol

Saliva and urine samples were collected in the morning and before/after judo events, as indicated in Table 2. Subjects were instructed to drink almost 1.5 l of water every day. After 1 year, athlete 1 was observed again, during an intense period of competition (Table 2).

Table 2. Saliva and urine monitoring program: the first period panel (A) is related to two athletes (1 and 2), whereas the second period panel (B) is referred to Athlete 1 but two year later.

First monitoring (Judo athlete 1 and 2)	Second monitoring (Judo athlete 1)*
1. Before normal training*	1. After summer rest time
2. Immediately after normal training	2. After intense training
3. 12 hours after normal training*	3. Before international stage
--	4. After international stage
4. Before competition*	5. Before/ after an European Cadet Cup
5. Immediately after national competition	6. Before/ after an European Cadet Cup
6. 16 hours after national competition*	7. Before/ after an European Cadet Cup
--	
7. Before national stage*	
8. Immediately after national stage	
9. 22 hours after stage*	

*Note. * All these specimens were sampled at 8:00 a.m.*

Stimulated saliva samples were collected in a sterile Salivette® (Sarstedt) without any additives. Subjects were instructed not to consume foods or beverages containing sugar, caffeine, or acid for at least 2 hours prior to sample collection. They were also asked not to undergo any dental treatment for at least 48 hours before collection and not to brush their teeth for at least 45 minutes before collection. Before sampling, the mouth is rinsed with water for at least 5 minutes, and then the first saliva produced is swallowed. The sample is collected by placing the Salivette® swab in the mouth and holding it for 2 minutes without chewing. The swab is passed from one side of the mouth to the other and then spat directly into the inner vial of the double chamber tube, sealed and stored at +4 °C until transport to the laboratory. Salivette® were centrifuged at 2000 ×g for 10 minutes to remove particles. Aliquots were immediately stored in vials and placed in the freezer (-20 °C) until analysis. Urine was collected in a sterile 50-mL falcon and transported in a cooler. Saliva and urine samples were rapidly transported to the laboratory and immediately frozen at -80 °C until analysis.

Creatinine concentration in urine

Creatinine concentration was estimated from each urine sample by the Jaffé (Jaffé, 1886) alkaline picrate method. Two reagent solutions were prepared:

Reagent 1: 0.6 g of pycric acid dissolved in 50 Ml of borate buffer (13.6 g of NaOH and 19.83 g of $Na_2B_4O_7 \cdot 10\ H_2O$ at final volume of 1L).

Reagent 2: 1M NaOH solution.

The working reagent was prepared by mixing reagent 1 and reagent 2 (1:1).

Briefly, 40 µL of urine was mixed directly with 360 µL of MilliQ water in a reduced volume spectrophotometer cuvette. Then 2.8 mL of working reagent was added and the mixture was allowed to stand in the dark at room temperature for 10 minutes after shaking. Then the absorbance at 500 nm was read and the creatinine concentration was calculated using a standard calibration curve.

FRAP assay

The FRAP (Ferric Reducing Antioxidant Power) assay is carried out under acidic conditions (pH = 3.6). The oxidant in the assay is prepared by mixing TPTZ (tripyridyltriazine as the iron-binding ligand), acetate buffer, and $FeCl_3$ and the mixed solution is referred to as "*FRAP reagent*" (Benzie and Strain, 1996). FRAP assay measures the change in absorbance at 593 nm due to the formation of a blue coloured Fe(II)-TPTZ compound from colourless oxidized Fe(III) form by the action of electron donating antioxidants.

Reagents:

1. Solution (A) Acetate buffer, 300 mM, pH = 3.6: add 3.1 g of sodium acetate trihydrate ($CH_3COONa{\cdot}3H_2O$) in 16 mL of glacial acetic acid (CH_3CO_2H) to final volume 1 L.
2. Solution (B) 10 mM 2,4,6-tripyridyl-S-triazine (TPTZ): add 0.312 g of TPTZ in 100 mL 40 mM HCl. The TPTZ is dissolved at 50°C.
3. Solution (C) 20 mM $FeCl_3$: add 0.360 g of iron(III) chloride anhydrous ($FeCl_3$) in 100 mL of MilliQ water.
4. Working FRAP reagent: mix the solutions A: B: C in the rate (10: 1: 1). The working solution must be freshly prepared.

Aqueous solutions of ascorbic acid in the range of 0.1-0.5 mM are used to calibrate the FRAP assay. The assay procedure requires a freshly prepared working reagent FRAP (3.0 ml) mixed with 100 µl of test sample or standard in a test tube. After stirring, the absorbance at 593 nm is read exactly after 6 minutes against a blank reagent sample.

Malondialdehyde assay

Malondialdehyde (MDA) was determined by the fluorometric method (Agarwal and Chase, 2002), which is based on the reaction of lipid peroxidation (LPO) by-products, such as malondialdehyde, with thiobarbituric acid (TBA) to yield a fluorescent compound.

Derivatization of the urine sample was performed according to the method described by Agarwal and co-workers (2002), and the MDA product was determined using a Dionex HPLC instrument equipped with an AD25 UV-Visual detector and a GF2000 fluorescence detector. The injection volume was 25 µL and the column was a LiChrospher RP-C18 (5 µm, 250 mm, Agilent). The fluorescence detector was set to an excitation wavelength of 515 nm and an emission wavelength of 553 nm.

Cortisol assay

Cortisol is determined in saliva samples according to the proposal of Pihut (Pihut et al., 2015) with some modifications. A certified reference cortisol from Sigma-Aldrich was used as a standard (1.0 mg-mL^{-1} in methanol, vial of 1 mL). Briefly, saliva samples were treated by adding 4 mL of dichloromethane to 1 mL of saliva. Stirred for 10 minutes and centrifuged at 10,000g for 7 minutes. The dichloromethane layer is separated and evaporated. The residue is collected in 100 µL of mobile phase (acetonitrile/water, 36:65 v/v), transferred to an Eppendorf tube, and centrifuged at 4,500 g for 4 minutes. The sample was then injected into the HPLC column (RP-C18) and analysed using an isocratic program at T = 25°C, λ = 240 nm, and a flow rate of 1 mL-min^{-1}.

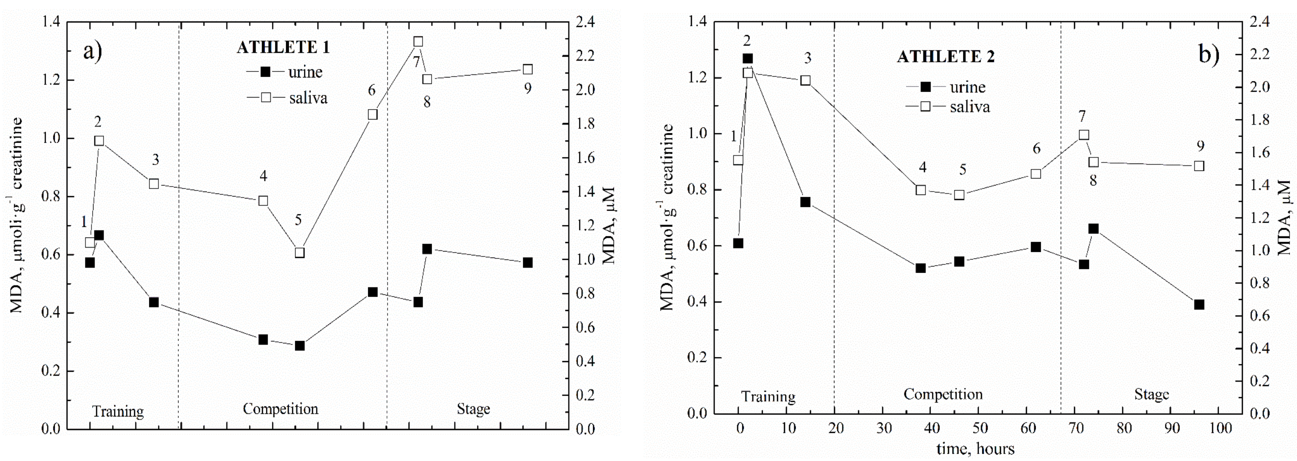
The area under the curve (AUC) for cortisol was calculated using the trapezoidal equations described in Fekedulegn et al. (2007).

Bilirubin fluorometric assay

200 µL of each diluted sample or BR standard solution was added to 10 µL of a HUG 1 g · L^{-1} (PBS, pH = 7.4) in a 96-well microplate (Nunc®) for fluorescence-based assays (Sist et al., 2022). The microplate was then incubated at room temperature for 2 hours, and fluorescence emitted from the BR·HUG complex was detected at λ = 528 nm after excitation at λ = 485 nm using a benchtop microplate reader (Synergy H1; BioTek, Winooski, VT). At this time, 4 units of β-glucuronidase were added, and total bilirubin was detected after overnight incubation at 25°C. The concentration of BR was determined from a calibration curve ranging from 0 to 15 nM. Conjugated bilirubin was determined as the difference between total bilirubin and unconjugated bilirubin.

RESULTS

In a biochemical study, it is recommended to use a series of assays, including different assays for total antioxidant capacity and different assays for oxidative stress markers. In the first part of our study, we examined the correlation between urinary and salivary MDA concentration in saliva and urine samples collected in the morning before and after judo competitions (see Table 2, panel A). Specifically, we wanted to test the hypothesis that salivary MDA concentration correlates with urine levels to provide a simple, reliable, and non-invasive method for determining MDA concentration in athletes during intense training activity and recovery after training. The formation of lipid hydroperoxides by oxidative lipid damage leads to the by-product of lipid peroxidation, such as malondialdehyde (MDA), which is formed by the cleavage of peroxidized fatty acids. MDA is usually measured by derivatization with thiobarbituric acid (TBA), yielding a red compound. The advantages of this method are the relatively short run times and the higher sensitivity and selectivity, especially for urine and saliva samples containing multiple co-elution interferences.



Note. Training: (1) before (8:00 a.m.); (2) immediately after; (3) 12 hours after (8:00 a.m.). Competition: (4) before (8:00 a.m.); (5) immediately after; (6) 16 hours after (8:00 a.m.). Stage: (7) before (8:00 a.m.); (8) immediately after; (9) 22 hours after (8:00 a.m.).

Figure 1. Salivary and urinary MDA concentrations as a function of time, during training/competition event for a) athlete 1 and b) athlete 2. Analyte concentration is divided by creatinine concentration to evaluate the difference in urine dilution.

Comparing the data in Figure 1a with those in Figure 1b, the overall mean shape of the MDA curves in the urine and saliva of the two athletes during the three events was very similar. It is noteworthy that the trends of the two MDA curves (urine and saliva) for each athlete are very similar and have the same range of variation, i.e., 0.6-1.3 µmol·g^{-1} of creatinine for MDA in urine and 1.0-2.3 µM for MDA in saliva. Of particular note, both saliva and urine values in Figure 1 show high peaks after intense aerobic activities such as a normal club training session (values 1-2-3) or a stage event (values 7-8-9) and, in contrast, lower values during a competition event, as shown in Figure 1. A significant increase in MDA levels (in urine and saliva) measured immediately after the training session (1-2-3) and stage (7-8-9) compared to the corresponding levels before the events is also shown in Figure 1. After a 12-hour recovery, MDA decreased significantly in both the samples.

A correlation plot of MDA in saliva and MDA in urine is shown in Figure 2. The regression shows a linear dependence of MDA in saliva on MDA in urine with a slope of 1.39 and an intercept of 0.81. A good correlation was found with Pearson correlation coefficient, i.e. r = 0.82.

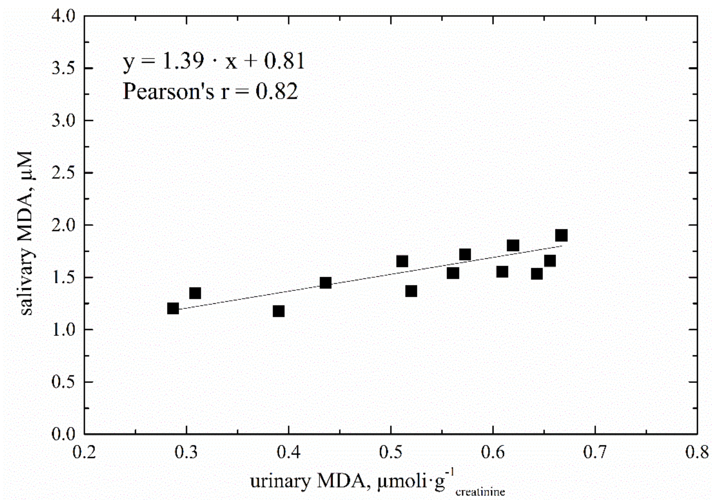


Figure 2. Correlation plot of salivary MDA vs. urinary MDA.

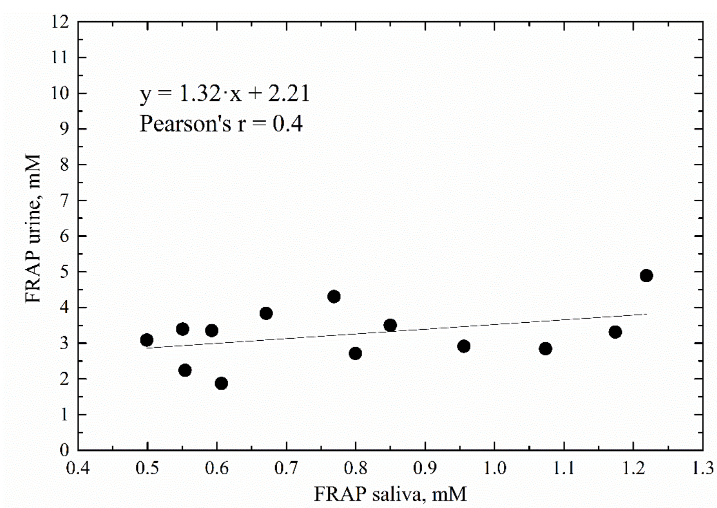


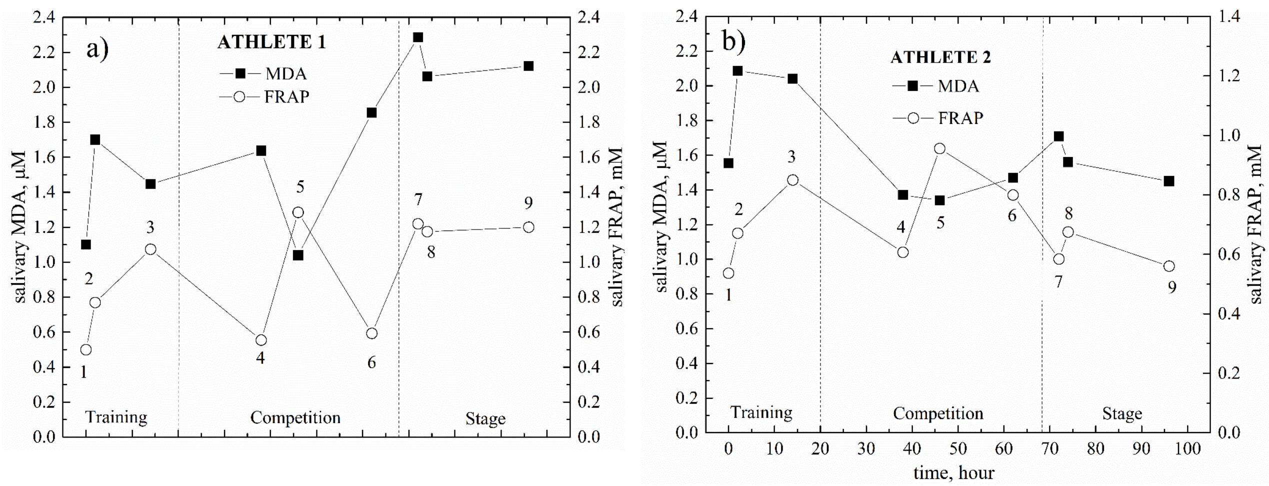
Figure 3. Correlation plot of salivary FRAP vs. urinary FRAP.

The results of the correlation allow us to monitor the athletes during the different moments of training or competition with greater punctuality and speed, since the implementation is very simple and the samples can be easily collected, stored and shipped, and they can be obtained at low cost in sufficient quantities for analysis.

The overall oxidative status of athletes was monitored in order to avoid imbalances caused by oxygen free radicals, which are responsible for fatigue status and diseases such as heart failure and muscle damage. In biological samples such as saliva or plasma, there are a large number of heterogeneous compounds with different antioxidant activities that are very difficult to measure separately, so antioxidant status is better represented by total antioxidant capacity as FRAP value.

Figure 3 shows the correlation between saliva and urine FRAP values. As with the MDA parameter, the results of the correlation allow us to monitor the athletes with greater speed and a very simple procedure by taking saliva samples.

In Figure 4 are reported salivary MDA concentrations and salivary FRAP values for athletes in the previous exercise conditions (Figure 1). There was a statistically significant effect of intense exercise on salivary antioxidant capacity FRAP, which increased after training/competition events compared with values measured before the events and decreased after 12 - 22 hours of rest.

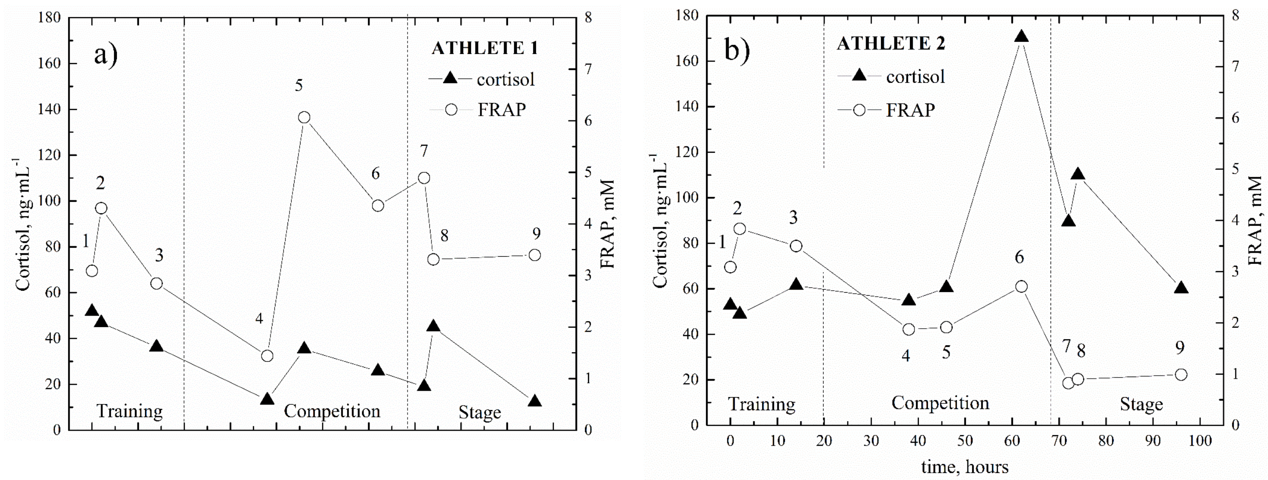


Note. Training: (1) before (8:00 a.m.); (2) immediately after; (3) 12 hours after (8:00 a.m.). Competition: (4) before (8:00 a.m.); (5) immediately after; (6) 16 hours after (8:00 a.m.). Stage: (7) before (8:00 a.m.); (8) immediately after; (9) 22 hours after (8:00 a.m.).

Figure 4. Salivary MDA concentrations and FRAP as a function of time, during training/competition events for a) athlete 1 and b) athlete 2.

Exercise is a physical stressor and activates hormonal systems, especially hypothalamic corticotropin-releasing hormone. In addition to physiological factors, the adrenocortical response to acute or chronic stress exercise is also influenced by psychological factors. Hormones associated with the hypothalamus and pituitary gland, such as salivary cortisol, have been proposed as useful biomarkers of oxidative stress and the decline in physical performance known as overreaching or overtraining. Moreover, salivary cortisol correlates strongly with free blood cortisol (r ≥ 0.90) and is independent of transport mechanisms and salivary flow (Kaufman et al., 2002). This correlation between salivary and serum oxidative biomarkers reinforces the utility of saliva as a valid diagnostic fluid.

Figure 5 shows the individual responses of salivary cortisol concentration in samples measured during the three events mentioned above.



Note. Training: (1) before (8:00 a.m.); (2) immediately after; (3) 12 hours after (8:00 a.m.). Competition: (4) before (8:00 a.m.); (5) immediately after; (6) 16 hours after (8:00 a.m.). Stage: (7) before (8:00 a.m.); (8) immediately after; (9) 22 hours after (8:00 a.m.).

Figure 5. Salivary cortisol and FRAP concentration as a function of time, during training/competition event for a) athlete 1 and b) athlete 2.

It is noticeable that total cortisol levels in Figure 5 show the same overall trend as antioxidant capacity, expressed by measurements from FRAP, which increase immediately or within 12 hours after competition and national stage events. It is well known that cortisol levels increases linearly in response to physical exercise until a specific threshold of exercise intensity is reached, with peak concentrations generally occurring at the end of physical activity (Ahtiainen et al., 2003; Filaire et al., 2001).

The values measured on the day of the competition (value 5 and 6 in Figure 5) were significantly higher than the values measured after normal training events. Significant cortisol differences were noted near the end of the competition, which has already been reported to increase stress, as measured by higher salivary cortisol levels (Moreira et al. 2013; Filaire et al. 2001) during judo competition, confirming previous reports of the existence of an anticipatory cortisol response to this type of situation. The peak cortisol increase is reported to occur at 20 min post-exercise in blood and at around 30 min post-exercise in saliva (Crewther et al., 2008; O'Connor et al., 1987). This response is similar to that found for other sports such as volleyball and basketball observed during an important match (Mazdarani et al. 2016; Moreira et al., 2013).

It is noticeable that the response of the two athletes is very different in terms of cortisol levels, with athlete 1 always having a lower cortisol salivary concentration (Figure 5).

The interindividual variability of cortisol levels measured in the pre-post events of Figure 5 is also shown as the change in the area under the curve (AUC) values in Table 3. The AUC is routinely used to account for multiple time values in monitoring over a period of time. Following Pruessner et al. (2003), the area under the curve was calculated using the trapezoidal formula to obtain the area under the curve with respect to rise (AUC_I) and the area under the curve with respect to ground (AUC_g). AUC_I is calculated with respect to the baseline (starting value) and highlights the changes as a function of time, while AUC_g expresses the total hormone release. In the repeated measurements. AUC_I takes into account both the sensitivity and intensity of changes in the pattern and takes both negative and positive values in terms of the shape and size of the curve, as in Table 3. Therefore, for patterns that have a sequence of increases and decreases over time, the AUC_I can be positive or negative depending on how much the increase is relative to the decrease.

Significant differences in the values of AUC_g were found between training event and competition as well as between competition and stage training as reported in Table. 3. These data shows that the value of AUC_g in the competition situation was higher than in the training situation in both athletes, namely from 597 to 681 (+14%) and from 762 to 2306 (+203%) in athlete 1 and 2, respectively. The competition situation may represent more psychological demand of athletes and influenced their perception of the difficulty and importance of the match. Moreover, athlete 1 showed an almost constant AUC_g value throughout the entire observation period, whereas athlete 2 showed an increase in AUC_g value of up to 200% during the competition. In addition, athlete 2 showed significantly higher AUC_g values than athlete 1. As reported in the literature, AUC_g and performance are related, with the greatest performance occurring in athletes who have low AUC_g values (Meggs et al., 2016). Therefore, AUC_g can be adopted as a measure to predict athletic performance in competition and may be useful in monitoring athletes' overall exposure. These differences can be better observed comparing the AUC_I values in Table 3, where the AUC_I is calculated with reference to the initial AUC value. Analysis of pre-post changes in cortisol levels showed high interindividual variability, which allowed us to distinguish between athletes with different HPA axis responses and adaptation to the same training load showing an increase, unchanged, or decrease in AUC_I levels.

Table 3. AUC cortisol data from first monitoring for athlete 1 and athlete 2.

Athlete 1		**Athlete 2**		
AUC_g	AUC_I	AUC_g	AUC_I	
597	-126	762	-25	1. Before normal training (8:00 a.m.) 2. Immediately after normal training 3. 12 hours after normal training (8:00 a.m.)
681	366	2306	996	4. Before competition (8:00 a.m.) 5. Immediately after national competition 6. 16 hours after national competition (8:00 a.m.)
691	238	2069	-86	7. Before national stage (8:00 a.m.) 8. Immediately after national stage 9. 22 hours after stage (8:00 a.m.)

Athlete 1 was then observed after one year when he additionally participated in higher level competitions, such as international competitions. Table 4 shows the data on MDA, cortisol, and bilirubin in saliva before and after competitions and training events. Bilirubin was included in our test battery as a preliminary outcome because it has widely been used in sports medicine to assess the degree of muscle damage or strain leading to haemolysis (Banfi et al., 2012.), but its contribution to the total antioxidant capacity of human blood is recently underlined (Witek et al., 2017).

Table 4 shows higher MDA values in the second period (B) compared to period A, which is likely due to the higher training load and volume in this year, especially during competitions.

Very low or no cortisol levels were detected during the period B training and stage events, mainly attributed to the current training and fitness status of athlete 1. In contrast, cortisol levels were significantly higher after the competition 3 than before the competition (Table 4), most likely due to cognitive or somatic anxiety: fear, panic, alarm, anxiety, apprehension, and symptoms caused by autonomic nervous system activation, such as accelerated heartbeat, sweating, etc., in cognitive anxiety situations (Hardy et al., 2009) confirming the anxiogenic nature of sports contests.

Table 4. Stress biomarkers for athlete 1 at two different moments (A and B) of his judo career.

Event monitored		**Training**		**Stage**		**Competition 1**		**Competition 2**		**Competition 3**	
		A	B	A	B	A	B	A	B	A	B
MDA $\mu mol \cdot g^{-1}$	Before	0.572	1.413	0.437	1.040	0.308	0.996	--	1.442	--	1.286
	After	0.436	1.007	0.573	0.628	0.471	1.200	--	0.921	--	0.999
Cortisol $ng \cdot mL^{-1}$	Before	51.70	0.00	18.90	0.00	13.11	0.00	--	1.76	--	22.66
	After	36.27	16.20	12.15	0.00	25.65	0.81	--	0.00	--	28.87
T-BR nM	Before	--	1.47	--	0.972	--	--	--	2.193	--	0.735
	After	--	--	--	2.295	--	0.609	--	0.626	--	2.871
BR nM	Before	--	0.547	--	0.851	--	--	--	1.142	--	0.478
	After	--	--	--	1.365	--	0.413	--	0.152	--	0.429
C-BR nM	Before	--	0.925	--	0.120	--	--	--	0.478	--	0.256
	After	--	--	--	0.930	--	0.196	--	0.429	--	2.442

Note. T-BR: total bilirubin, BR: bilirubin, C-BR: conjugated bilirubin.

Bilirubin has also been measured in salivary samples as an antioxidant and anti-inflammatory biomarker, as it can act as an antioxidant defence against ROS attacks and its level can be stabilized by a good exercise protocol. Our preliminary results on all three bile pigments in athlete 1 (Table 4) shows a correlation between salivary bilirubin and cortisol. The role of free and conjugated bilirubin found in saliva deserves further investigation and correlation with changes in plasma bilirubin.

DISCUSSION

In the present study, a number of oxidative stress biomarkers were examined before and after a training, stage, or competition situation. The main findings of the current study were that aerobic and anaerobic disciplines such as judo can cause an increase in oxidative stress when the antioxidant system is inefficient in response to additional free radical production during exercise. However, when training programs are long and intense enough to establish a consistent adaptive response of the antioxidant system, a decrease in oxidative stress occurs. It can be concluded that regular judo training may serve as a stimulus to enhance endogenous antioxidant protection in judoka through their regular and strenuous training. Routine monitoring of judo athletes requires only non-invasive sampling performed immediately after training or competition. In addition, the ability to store biological samples at low temperature prior to analysis without compromising the determination of chemicals is critical for the study of elite athletes in various geographic locations. We have shown that the response of athletes to intense training can be measured in a reliable and non-invasive manner by serial saliva sampling, in part because the transfer of markers from blood to saliva is relatively rapid, for example, cortisol within 2-3 minutes. In addition, the monitoring procedure is simple and applicable under a wide range of training and competition conditions. Moreover, the procedure avoids the need to draw blood samples from the vein, which is associated with additional stress and can lead to false positive results.

From the preliminary results obtained here, it appears that the two athletes considered respond very differently to the tests, despite having the same training and experience. Thus, in monitoring oxidative and psychophysiological stress, each individual is a reference in itself and the average over a population of athletes may not be representative. FRAP assays have the advantage of being able to account for the individual antioxidant effects of different substances and their additive, synergistic, or antagonistic interactions. Increased antioxidant capacity need not be a desirable state if it represents a response to increased oxidative stress. Similarly, a decrease in antioxidant capacity may not necessarily be an undesirable state if the measurement reflects decreased production of reactive species.

Salivary cortisol is a representative marker of circulating free cortisol and can be used as an index of exercise stress while avoiding venepuncture-induced stress. Therefore, cortisol is used to measure psychophysiological stress during single or repeated training sessions or competitions by relating the intensity of anxiety and salivary cortisol concentration before and after the competition. Another aspect to consider is that cortisol taken and measured from serum or plasma represents total cortisol and not free, biologically active cortisol.

The differences in cortisol levels found in this work may be due, at least in part, to differences in physical exertion, but the psychological stress of competition contributes significantly to the physiological stress caused by exertion. It is important to remember that stress hormones such as cortisol cause immune suppression and resistance to infection decreases in athletes after intense and prolonged exercise. In the present study, individual data showed significant inter-individual variability in pre- and post-exercise cortisol level changes and area under the curve (AUC) values. This observed variability is the result of the different response of the hypothalamic-pituitary-adrenal (HPA) axis to exercise stress, which leads to a different physiological adaptation of the neuroendocrine system of athletes. These data relate to the individual response to the stressor and suggest that the individual monitoring protocol is preferable to smoothed averages of the athlete population. In addition, monitoring hormonal response to exercise may be a useful indicator of excessive fatigue and the onset of overreaching or overtraining status. A significant increase in cortisol levels at rest indicates the onset of overtraining.

Cognitive anxiety has been shown to take on high values before a competition and to remain relatively high and stable at the beginning of the competition. Somatic anxiety, on the other hand, has relatively low values until about 12-24 hours before the competition. Thereafter, a rapid and significant increase is observed as the start of the competition approaches. Throughout the duration of the competition, cognitive anxiety and, consequently, cortisol levels vary as a function of the probability of success/failure, whereas a rapid decline was observed in somatic anxiety levels. In addition, several studies reported that cortisol levels varied between winners and losers, with losers having higher cortisol levels, especially immediately after competition (Fernandez-Fernandez et al., 2015).

Bilirubin has been shown to be a molecule with multiple functions. In the past, it was a degradation product with toxic effects, especially in infants. In recent years, it has assumed various physiological meanings, and important antioxidant, anti-inflammatory, and regulatory effects have been attributed to it. The evaluation of the baseline level of bilirubin in saliva and its changes after stressful situations is an innovative measure that is not currently used because the concentrations are very low and cannot be detected by conventional analytical methods.

This simple salivary test battery for oxidative and psychological stress needs to be complemented by other stress biomarkers such as amylase, testosterone, lactic acid, IgA/IgM, enzymatic activities (SOD, peroxidase), uric acid, which would be particularly useful out of competition during a period of reduced training, such as during a recovery period or during a taper, where it is important to determine the psychophysiological profile of an athlete in preparation for competition.

The analysis of pre-post changes in cortisol level showed the existence of a high-interindividual variability which allowed us to distinguish between athletes with different HPA axis adaptation to the same training load. This work encourages further research into the effects of the training program in athletes to prevent fatigue and injury and to maintain the health of these athletes.

CONCLUSIONS

Heart failure and muscle damage are two phenomena that affect professional and elite athletes. In particular, heart failure occurs in 1/100,000 athletes, while the incidence of muscle injury in athletes is about 30-40% of total injuries. In addition, fatigue in athletes is a common but difficult to diagnose condition. While some degree of fatigue may be normal in any athlete during periods of high training volume, it is very important for sports physicians to distinguish between this physiological fatigue and more prolonged and severe fatigue, which is often due to certain pathological conditions. It is well known that stress is one of the factors highly associated with the possibility of injury. During stressful periods, muscle strains and minor injuries are more frequent, even during simple activities.

In summary, it seems possible that the ROS- and RNS-induced reduction in maximal force production may be part of a protective mechanism by which skeletal muscle protects itself from further peak force-generated damage. In addition, it has been suggested that repetitive muscular ROS-induced fatigue combined with inadequate recovery may trigger an overtraining syndrome.

Aerobic, anaerobic, or mixed exercise causes increased production of free radicals. Similarly, humans respond adaptively with increased mobilization of a variety of enzymatic and non-enzymatic antioxidants in cells or plasma. However, in most cases, antioxidant capacities are exceeded, leading to oxidative stress, which is even more important when training intensity and duration are high and subjects have low training levels and inadequate nutritional status. This exercise-induced improvement in antioxidant status and reduction in oxidative stress have been extensively documented in the literature. However, some studies report a decrease in the efficiency of the antioxidant system, particularly in high-performance athletes exposed to high training and competition loads with inadequate nutrition. These studies suggest a threshold at which oxidative stress may increase excessively and lead to overtraining. Indeed, the free radicals generated during exercise play an important role in the development of muscle damage, but also in the development and spread of post-exercise inflammation, which can exacerbate cellular damage. The totality of these phenomena can be the cause of muscle fatigue and injury, disrupting muscle function and leading to overtraining syndrome.

AUTHOR CONTRIBUTIONS

Paola Sist: Sample collection, Methodology, Investigation, Writing-original draft, Result and Discussion. Ranieri Urbani: Methodology, Formal Analysis, Software, Writing-original draft, Critical Revision and Discussion, Review and Editing.

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SCIENTIFIC JOURNAL OF SPORT AND PERFORMANCE

ORIGINAL ARTICLE

Inter-distance differences in aiming error and visual perception influence shooting performance in basketball

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ABSTRACT

This study is the first to use inter-distance differences in shooting direction error to investigate the influence of visual perception on basketball shooting performance. Thirty-two experienced basketball athletes (NCAA Division I-III: n = 15, Canadian U Sports Association: n = 13, National Basketball Association: n = 4) attempted blocks of 25 jump shots from a near (free throw) and far distance (three-point attempt). Differences in the root-mean-square deviation of lateral direction error as distance increased, Δ_{LDE}, were used to measure an individual's change in lateral accuracy as the target changed within their visual field. The mean Δ_{LDE} was -0.18 degrees ($p < .001$, 95% CI: -0.25 – -0.11) indicating that an individual's lateral direction accuracy worsened as shooting distance decreased and external visual cues transitioned away from their central vision. Shooting performance had a strong positive correlation with Δ_{LDE} ($r = 0.57$, $p = .001$) indicating that better shooters have a higher ability to adapt to the changes in visual perception with distance and experienced smaller reductions in lateral accuracy as shooting distance decreased. These findings show that visual perception has a significant role in basketball shooting performance and that Δ_{LDE} is a valuable measure for assessing how an athlete's proficiency in visual perception contributes to their performance.

Keywords: Performance analysis of sport, Physical conditioning, Free throw, Jump shot, Far aiming, Visuo-motor control.

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INTRODUCTION

Sports research on far target aiming such as shooting in basketball has found that visual perception and gaze are strongly linked to performance (Klostermann et al., 2018; Poltavski and Biberdorf, 2015). Specific vision training has been shown capable of enhancing performance in basketball and soccer (Harle and Vickers, 2001; Vickers et al., 2017; Savelsbergh et al., 2010). While some visual functions are associated with improved performance, it has also been shown that basketball shooting can be resilient to high levels of visual degradation such as retinal defocus and occlusion (Bulson et al., 2015; de Oliveira et al., 2006; Vickers, 2007). Although it is evident that vision plays an important role in basketball shooting performance, uncertainty remains regarding many of the details within the combined visuo-motor task such as timing, region of attention, and response to pressure situations.

The two most prominent areas of vision research concerning shooting in basketball are gaze fixation which emphasizes eye-tracking and studies investigating visual timing which often utilize segments of occluded vision. In gaze behavior, the phenomenon referred to as quiet eye (QE) refers to the duration of a target fixation preceding a final motor response (Vickers, 2007; Vickers, 2009). Researchers have reported that early visual fixations and longer QE periods are strong predictors of motor performance (Lebeau et al., 2016; Rienhoff et al., 2016; Vine and Wilson, 2011). This has led some to theorize that aiming movements are preprogrammed before execution (Vickers, 2016; Vickers, 1996; Klostermann, 2019). The other ecological studies using intermittent vision or timed occlusions have found that long fixations are not required for good performance (Oudejans et al., 2002; de Oliveira et al., 2007). Even when vision is occluded for significant early portions of a shot attempt, good performance still occurs (de Oliveira et al., 2006), suggesting that late vision was most important (de Oliveira et al., 2007). These findings have led to theories prioritizing the role of online control (de Oliveira et al., 2006; Oudejans et al., 2002; de Oliveira et al., 2007; de Oliveira et al., 2009).

The competing viewpoints emphasizing the importance of gaze duration as compared to the timing of acquisition of visual information, however, usually complement and/or qualify each other rather than contradict. Their mutual dependence is supported by the findings of Schütz et al. (2013) who hypothesized that gaze-dependent and gaze-independent information may be shared during visual processing rather than being dissociable. Both viewpoints acknowledge that neither is sufficient to fully explain how visual information is used in far aiming tasks with Vickers et al. (2019) and de Oliveira et. al. (2008) providing insight into how the theories compare, contrast, and interact.

There remains much unknown about how visual information is processed in far aiming tasks such as basketball shooting. This is partially due to distinct limitations of the methodologies used to investigate gaze behavior and timing which restrict the scope of their conclusions. The use of eye-tracking provides gaze location and duration, but it doesn't reveal the level of attention or use of the visual periphery. In contrast, occluded vision may inform the timing of relevant visual information but cannot specify which details provide essential cues. Three visual functions relevant for successful performance in sports are not captured by either eye-tracking or occlusion methodologies. The first is the integration of peripheral and central vision with Ryu et al. (2013) suggesting that gaze may only reflect a central vision anchor point from which peripheral information is extracted. Second, the presence of landmarks near a target has been found to reduce aiming error and may combine with other allocentric information even when targets are temporarily occluded (Schütz et al., 2013). Third, neither methodology captures the ability of egocentric position, direction, and allocentric perceptions to respond differently to visual variations (Schütz et al., 2013; Nakashima et al., 2015) and thus an important performance factor may be their ability to interact as a single shared visual perception.

This study aims to investigate how these visual functions contribute to performance in the far aiming task of basketball shooting. Lateral direction errors in the sagittal plane are compared for conventional jump shots taken from a near (free throw) and far distance (three-point attempt). The variation in distance provides several target differences within the visual field. First, closer attempts result in a visually larger target hoop within central vision as compared to attempts from farther distances. Next, landmarks such as the shooting square on a regulation backboard, which is intended to provide a visual guide, and the backboard will transition from peripheral to central vision as shooting distance increases. Another variation is that the ball and/or hand will either fully or partially occlude vision of the target at some time during the attempt as the ball move in front of the face. At closer distances, the portion of the target and duration occluded will be less than when shooting from a farther distance.

As shooting distance is increased, three possible responses in lateral direction error exist. If lateral control is unaffected by changes in visual perception with distance, no significant effect would be found in lateral direction error since others have already shown that increases in motor noise are largely absent when transitioning from free throws to three-point attempts (Slegers et al, 2021). However, if lateral direction errors increase with distance, it would indicate that changes in visual perception with distance increase the task complexity. The third possibility is that lateral direction errors decrease with distance, suggesting that changes in visual perception with distance decrease complexity. It's hypothesized that the movement of landmarks toward central vision and the visually smaller target with increasing distance will provide more benefits to lateral accuracy in basketball shooting than any hindrances from increased target occlusion. Therefore, the first hypothesis is that aiming error will decrease as distance increases from free throws to three-point attempts. It's also hypothesized that better shooters will demonstrate a higher ability to adapt to changes in visual perception with distance and will have smaller changes in lateral aiming error as distance changes.

MATERIALS AND METHODS

Participants

Thirty-two basketball athletes (n = 32) were recruited for this study (males: n = 24, age = 21.8 ± 3.3 yrs, height = 190 ± 10 cm; females: n = 8, age = 20.7 ± 1.5 yrs, height = 172 ± 6 cm). Participants were actively involved in institutionally sponsored competitive basketball teams (NCAA Division I-III: n = 15, Canadian U Sports Association: n = 13, National Basketball Association: n = 4) with 3.8 ± 3.1 years of post-secondary playing experience. Each participant gave their voluntary consent for inclusion in the study, which was approved by the local ethics committee.

Measures

Lateral error (LE) for an attempt is defined as the deviation of the ball center from the sagittal plane when the lowest portion of the ball falls to the height of the target hoop (3.05 m). Positive and negative distances indicate misses to the right and left, respectively. The ball center is identified by using three points on the edge of the ball to estimate its geometric center where the width of the shooting square (0.61 m) on the backboard is used as a calibration distance.

Lateral shot deviation in basketball varies linearly with distance, i.e. the ball doesn't swerve, meaning that for a fixed error in throwing direction the final lateral error at the target increases as the shot attempt distance increases. To compare lateral control and isolate visuo-motor effects at different distances the performance indicator used in this study is lateral direction error rather than lateral distance error. Lateral direction error (LDE) is defined as the ratio of LE to shot attempt distance and has two interpretations as illustrated in Figure

1. First, LDE can be interpreted as the target aiming error since *tan*(LDE) ≈ LDE for small angles. Alternatively, LDE can also be viewed as a distance normalized lateral error (slope). Both perspectives are presented simultaneously in this study with a lateral error of 0.07 m from the free throw line (4.57 m) reported as an LDE of 0.88 deg (1.53 cm/m) to represent both the aiming and normalized lateral error. The root-mean-square deviation (RMSD) of LDE for each participant is used as a measure of their lateral aiming accuracy and addresses both aiming variance and bias. The total shooting percentage is determined by calculating the make percentage including both free throw and three-point attempts and is used as an additional performance indicator to quantify overall participant accuracy and skill level.

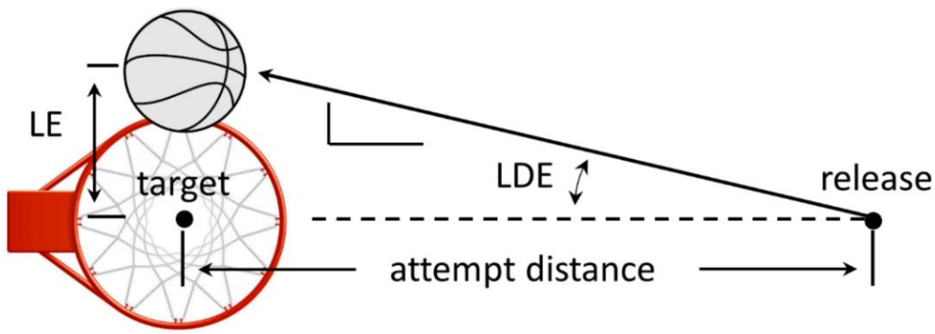

Figure 1. Top view of target illustrating the interpretations of LDE as both an aiming error and normalized lateral error (slope).

Procedures
Participants attempted blocks of 25 jump shots on a regulation height hoop (3.05 m) from both the free throw line (4.57 m) and regulation three-point line (female: 6.75 m, male: 7.13 m). The order of blocks was counterbalanced across participants to reduce sequence effects. To ensure a typical jump shot at each distance, attempts began with the participant throwing the ball up, catching the ball off one bounce, then directly proceeding into a shooting motion. All attempts were taken directly facing the backboard. Each shot was recorded using a tripod-mounted 1080p HD digital video camera, at 120 fps, and with a shutter speed of 1/720 seconds. The camera was placed 1.5 m behind the shooter, within the sagittal plane, 2.5m above the floor, and directly facing the target hoop. Processing of digital video for each attempt was done using Tracker 6.0.7 software (Open Source Physics Java framework).

Analysis
Statistical analysis was performed in Matlab v9.2.0 R2017a (Mathworks Inc., Natick MA, USA). Descriptive statistics are presented for participant root-mean-square deviation (RMSD) of LDE for both free throws and three-point attempts. The intra-individual change in LDE RMSD between three-point attempts and free throws is presented as Δ_{LDE} where positive values indicate the RMSD is higher for three-point attempts than free throws. Individual total shooting percentage is presented as a mean ± SD. A paired t-test was used to determine if Δ_{LDE} is significantly different than the null hypothesis and Cohen's d was used to estimate effect sizes (ES), in which d = 0.2, 0.5, and 0.8 were interpreted as small, medium, and large, respectively. For each t-test, an Anderson-Darling test was used to verify the data didn't significantly vary from normality. A test-retest reliability analysis was performed on one participant for lateral error to assess the reliability of the digitization of the ball center. The reliability coefficients and SD of test-retest differences were 0.997 and 0.6 cm for free throws and 0.998 and 0.5 cm for three-point attempts. All correlations are presented using the

Pearson product-moment coefficient, r, and interpreted as almost perfect (> 0.9), very strong (> 0.7), strong (> 0.5), moderate (> 0.3), weak (> 0.1), or trivial (< 0.1). In all cases, statistical significance was set at .05.

RESULTS

Descriptive statistics, presented as means, SD, and ranges, are provided in Table 1 for inter-individual free throw LDE (LDE_{FT}) RMSD, three-point LDE (LDE_{3PT}) RMSD, the intra-individual difference between three-point and free throw LDE RMSD (Δ_{LDE}), and participants' combined shooting percentage composed of both free throw and three-point jump shots. Intra-individual changes in LDE RMSD with distance, Δ_{LDE}, are provided as a box plot in Figure 2 where a t-test results in a mean Δ_{LDE} of -0.18 degrees (p < .001, 95% CI: -0.25 – -0.11, Cohen's d = 0.95) or -0.31 cm/m (p < .001, 95% CI: -0.43 – -0.19, Cohen's d = 0.95). In general, LDE RMSD among individuals is lower for their three-point attempts than their free throws (Δ_{LDE} < 0) with only five participants having a marginally positive Δ_{LDE}. This suggests that as the jump shot distance increased, participants typically decreased their LDE RMSD, or as distance increased, participants were more accurate with their lateral direction when compared to closer attempts.

Table 1. Descriptive statistics of lateral direction error and shooting percentage (n = 32).

Variable	Mean	SD	Range
LDE_{FT} RMSD, deg (cm/m)	0.93 (1.63)	0.24 (0.42)	1.37 – 0.53 (2.38 – 0.92)
LDE_{3PT} RMSD, deg (cm/m)	0.74 (1.23)	0.15 (0.26)	1.05 – 0.41 (1.84 – 0.71)
Δ_{LDE}, deg (cm/m)	-0.18 (-0.31)	0.19 (0.33)	0.18 – -0.68 (0.31 – -1.12)
Combined percentage (%)	70	12	91 – 48

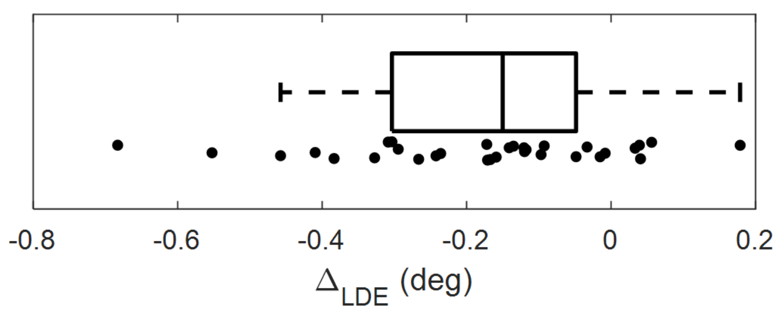

Figure 2. Box plot of Δ_{LDE}, the difference between three-point and free throw LDE RMSD.

Figure 3a illustrates the relationship between LDE RMSD and combined shooting percentage for both free throws and three-point attempts with both exhibiting very strong negative correlations (FT: r = -0.88, p < .001 3PT: r = -0.67, p < .001). This indicates that better shooters in this study, as determined by combined shooting percentage, have lower LDE RMSD and are more laterally accurate at both distances. Slopes (β_1) of each linear regression in Figure 3a are negative (FT: β_1 = -1.8 deg/%, 95% CI: -2.1 – -1.4, 3PT: β_1 = -0.87 deg/%, 95% CI: -1.2 – -0.52), where the larger negative slope for free throws results in the LDE RMSD difference between three-point and free throw attempts being more pronounced for poor shooters and decreasing as the combined shooting performance increases. This trend is illustrated in Figure 3b with Δ_{LDE} and combined shooting percentage having a strong positive correlation (r = 0.57, p = .001). Combined, the results from Figure 2 and 3b show that while the participants demonstrated more lateral precision (smaller LDE RMSD) as shooting distance increased, better shooters had smaller differences between the distances than the less accurate shooters.

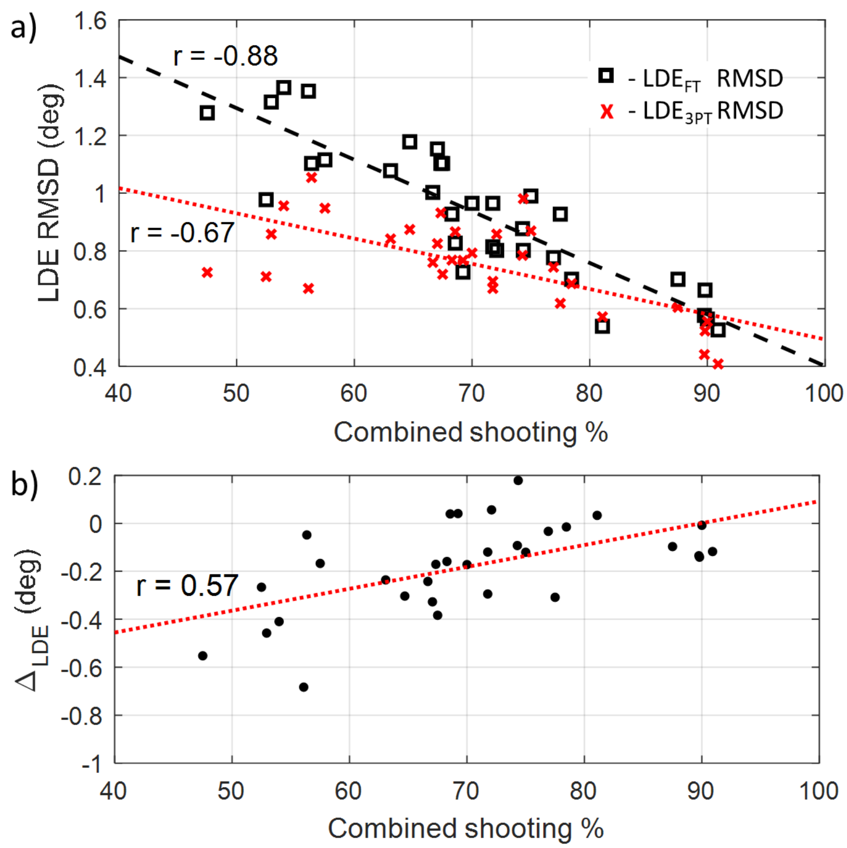

Figure 3. Lateral direction error vs. combined shooting percentage a) Comparison of free throw and three-point LDE RMSD b) Difference between three-point and free throw LDE RMSD, Δ_{LDE}.

DISCUSSION

Changes in lateral direction error with distance

A primary finding of this study is that LDE RMSD decreases as distance increases ($\Delta_{LDE} < 0$ in Figure 2). Therefore, the first hypothesis that aiming error decreases as distance increases from free throws to three-point attempts is accepted. The reduction in LDE RMSD with increased distance suggests that the visuo-motor complexity of aiming within the sagittal plane decreases with distance. The decrease in complexity can be attributed primarily to changes in perception within the visual field since any velocity-dependent motor noise effect would have led to an increase in Δ_{LDE} with increased distance, in contrast to the current findings. The absence of any significant contribution from velocity-dependent motor noise on lateral direction error is consistent with the results from Slegers et al. (2021). They showed that as distance is increased from free throws to three-point attempts, variation in longitudinal error remains unchanged since the required increases in force with distance are well within participants' ability and don't approach a maximal force task. Similarly, it has been observed that for three-point attempts, release strategies are not significantly influenced by velocity-dependent motor noise effects since shooters use strategies that maximize their success rather than using a minimum velocity (Slegers, 2022).

From among the changes to the visual field, the decrease in LDE RMSD with distance suggests that neither the increased spatial or temporal occlusion of the target by the hand and/or ball during the shooting motion as distance increases pose a significant challenge to regulating LDE. This agrees with earlier results that conclude basketball shooting performance is robust to even significant occlusion of vision throughout the shooting motion (Oudejans et al., 2002; de Oliveira et al., 2007, de Oliveira et al., 2008). Therefore, one or both of the remaining changes to the visual field as distance increases, a visually smaller target hoop within the central vision, and the transition of external landmarks (shooting square and backboard) from peripheral to central vision must contribute to increased lateral accuracy with increasing distance. A theoretical basis for central vision's role in LDE is provided by van Maarseveen et al. (2018), who contrasted peripheral vision's role in decision making and the reliance on central vision for execution. The latter is more closely related to the visuo-motor task of shooting. A limitation of this study is that the contribution from a visually smaller target and landmarks moving toward central vision cannot be isolated. All that can be said is that either one or both are beneficial for reducing LDE.

This study provides further evidence that in the far aiming task of shooting in basketball, the processing of visual cues is a significant contributor to performance. Within the context of earlier studies that investigate gaze behavior using QE and timing, the changes in the visual field from an increased distance observed here demonstrate that multiple visual cues may be essential and used simultaneously. Similar to the findings of Schütz et al. (2013) and Nakashima et al. (2015), overall visual processing that leads to the mean $\Delta_{LDE} < 0$ likely shares multiple features which are not dissociable.

Performance and inter-distance lateral direction error variation

While LDE RMSD decreased with distance ($\Delta_{LDE} < 0$) for most participants regardless of performance, Figure 3b illustrates that the effect decreases as the total shooting percentage increases. Using Figure 3a it's observed that for the best shooters, with shooting percentages greater than 90%, LDE RMSD converges at approximately 0.5 degrees for both distances representing $\Delta_{LDE} = 0$. Elite shooters, therefore, can maintain similar levels of LDE RMSD at different distances while less accurate shooters appear to increase LDE RMSD (decrease direction accuracy) as target visual cues move away from central vision as distance decreases. Therefore, the hypothesis that better shooters demonstrate a higher ability to adapt to changes in visual perception with distance and will have smaller changes in lateral aiming error as distance changes is accepted.

The coefficient of determination, $r^2 = .33$ in Figure 3b, shows that 33% of the variance in Δ_{LDE} is accounted for by the linear relationship with the total shooting percentage. This level is consistent with another study in which r^2 was .27 and related shooting percentage and lateral error induced by spin axis variation (Slegers and Love, 2022). A coefficient of determination near one-third is expected since longitudinal distance errors are the dominant cause of missed attempts and are approximately twice as common as lateral misses (Slegers et al., 2021; Slegers and Love, 2022).

These findings highlight that visual perception and processing is an important factor in basketball shooting performance. Results suggest that one way better shooters distinguish themselves is in their more developed visuo-motor ability that is less sensitive to the location of the target or other visual cues within central vision. Although this study did not assess gaze duration, and QE studies don't reveal the level of attention or use of the visual periphery (Vickers, 2009; Vine and Wilson, 2011; Vickers, 1996; Vickers, 2016), it's speculated that longer QE periods may be one way better shooters can quickly focus on the target and maintain lateral accuracy as distance is decreased even as important visual cues transition away from their central vision.

Implications for improving basketball shooting performance

Coaches and athletes may find that Δ_{LDE} provides a simple means of assessing an athlete's proficiency in visual perception related to basketball shooting or other sports with similar far aiming tasks. An advantage of using Δ_{LDE} as a metric is that it requires no special equipment unlike gaze fixation, QE, and visual occlusion, yet captures many of the dissociable features relevant to visual perception. Based on the results of this study it's suggested that a $\Delta LDE < -0.2$ deg (-0.35 cm/m) may indicate a visual perception deficiency in competitive basketball players. The use of Δ_{LDE} in addition to typical shooting performance measures such as shooting percentage may be valuable when assessing players who have mismatches in expected shooting percentages of free throws, undefended attempts, and in-game attempts. Mismatches in the expected performance among these categories may suggest that certain athletes find certain types of shots more challenging. In such cases, a below-average Δ_{LDE} may indicate a visual perception deficiency rather than a problem with shooting technique.

Since a below-average Δ_{LDE} indicates an athlete increases lateral aiming error as visual cues transition away from their central vision, practice designed to exercise such a condition may be beneficial for improving aiming performance. Regarding basketball shooting performance, the findings in this study may also guide coaches in developing training to improve visual function by implementing drills that mimic the process of quickly identifying the target and shooting in conditions in which visual cues are less prominent within the central vision, both stressing the visuo-motor system. Coaches can further develop customized practice methodologies by including defenders and making changes based on specific players' positions to further develop an ability to quickly identify and focus on the target within the central vision.

CONCLUSIONS

It was observed that visual functions such as peripheral vision, central vision, landmarks, and allocentric information play an important role in aiming accuracy and basketball shooting performance. Basketball players were found to reduce their lateral direction error as shooting distance increased ($\Delta_{LDE} < 0$) and visual cues of the target and external landmarks transitioned from their peripheral to central vision. The change in visual perception of a target as distance increased appeared to simplify the far aiming task and improve lateral accuracy. A significant finding of this study was that better shooters were more capable of maintaining low levels of lateral direction error even as the benefit of visual cues was reduced with decreasing distance. The difference in lateral direction error with distance, Δ_{LDE}, decreased as the total shooting percentage increased and approached zero for the best shooters. The use of Δ_{LDE}, or simply qualitative changes in lateral accuracy with distance, may provide coaches and athletes a means to identify potential deficiencies in visual perception acumen concerning far aiming tasks. Regarding basketball shooting performance, the findings in this study may also guide coaches in developing training to improve visual function by implementing drills that mimic the process of quickly identifying the target and shooting in conditions in which visual cues are less prominent within the central vision.

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