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LETTER TO THE EDITOR

Scientific Journal of Sport and Performance: A new trend of physical exercise and sports performance in 2022

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Dear Editor:

In these current moments of global uncertainty due to the pandemic, the world of Physical Activity and Sport Sciences is facing the reality of a new positioning in the basic priorities of people, since it is incorporated into the list of attributes most important in our society. The impact of this transition will not only affect the economy of sport, or sports tourism, but also the assistance of a total introduction of physical exercise in human beings. This transition will lead the Sports Science system to accept that it will have constant leadership, like any other scientific field. At the same time, the dissemination of knowledge that emanates from research groups and authors from all over the world must be exposed in a free and democratic way to achieve an arrival of science to humanity.

The different training methods will be used for the different biological and psychological profiles of each individual. Together with the use of the digitalization of the teaching and training process in physical activity, all the sets of scientific contributions on methodologies in physical exercise will be necessary for society to advance and the educational system to transfer it.

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Any normalization of the introduction of physical exercise supporting health and performance will be a necessary reinforcement. Now, more than ever, the digital function of sports coaches, teachers, and analysts has become the true support of the citizens. The virtual action of the training process driven by the need for confinement has been used as a single option at a time of high contagion, but it cannot be the usual tool, we must know how to use it and live with the usual form of sports practice.

The loss of motor skills in society is one of the great challenges that our publication will try to help reduce. The impact of COVID has brought us new challenges that we must work on, investigate and publish, from children's classrooms to elite sports.

The worrying gender gap in the field of Physical Activity and Sport Sciences will be one of the cross-cutting issues that the Scientific Journal of Sport and Performance should address without complexes. We must remember that research on the female gender in our field only reaches 32% of world publications.

The World has come to see that ecology is fundamental to our survival on this planet. Therefore, our scientific journal must confirm this global trend, promoting studies of ecological motor transport, and the development of sustainable mobility from the perspective of physical activity and health.

Nutrition and physical activity have formed an inseparable binomial, since the construction of a scientific bridge of added value. In 2022, high-impact international publications defend this marriage, which is undoubtedly the heritage of our vital history on this planet, as reflected in publications such as "*Sapiens*".

The impact of the new metaverse, one of the concerns of this editorial team will be the mental health of the citizens. Mental health has a direct impact on society and the economy and alters the life plans of people who suffer from this type of pathology. The recovery of people suffering from mental health disorders has a positive impact on employment, but it is necessary to work on their incorporation into the labour market. Physical exercise is the real medicine to combat this silent pandemic.

Robotics and artificial intelligence as new specialties within Sports Sciences will be a priority in our publication. It is true that the new constructions mentioned must be contemplated from legality and justice in this promising 2022.

The kinesiology of movement is a fundamental pillar of innovation in this time of recovery of world society. From our publication, we will delve into the scientific verification of different materials and instruments that help us live longer and in a better quality of life.

In addition to the foregoing, this publication will publish scientific conference proceedings and articles as the standard numbers of the publication progress. Virtuality is a resource that has made it possible to avoid trips and not interrupt the necessary training, research and networking between professionals and specialists in the field of Sports Science provided by scientific congresses.

The sports and motoring sector has managed to fight against climate change; it is a priority of the European Union, of the UN (2030 agenda). For this reason, we will try to request the authors, as far as possible, the following elements that favour this objective: virtual abstracts, infographics, video-abstracts and virtual guides.

Our conviction with this new editorial project in "*Scientific Journal of Sport and Performance*" is the search for knowledge to achieve a better world society and, above all, more human.

Keywords: Physical activity, Sport sciences, Performance analysis of sport, Physical conditioning, Physical education, Physical activity psychology, Sport medicine, Sport history.

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SCIENTIFIC JOURNAL OF SPORT AND PERFORMANCE

ORIGINAL ARTICLE

Multicomponent elastic training improves short-term body composition and balance in older women

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ABSTRACT

Multicomponent training is an effective modality to prevent and/or counteract certain physical, physiological, cognitive and emotional alterations of aging. Meanwhile, it is still unknown which specific methodological aspects of the training are more effective to achieve a better practical application. Objective: to assess the short-term effects of multicomponent training including some elastic exercises on body composition and balance in healthy older women. Methodology: In two sessions/week for 12 weeks, 24 women performed 4 blocks of exercise in 2 experimental conditions: a) Control Group; b) Multicomponent Training Group (EMC). The following were assessed: % of body fat, static balance in tandem position, static balance raising one leg with eyes open/closed, dynamic balance through the 4 m maximum speed walk test without running. An independent samples t-test was used to determine at the between-group level the effects of the intervention over time on the dependent variables, and a related-samples t-test was subsequently performed to detect possible differences over time. intragroup level. Results: there were significant inter-group differences ($p < .05$) in the variables of balance in tandem, with eyes open/closed and dynamic. Likewise, there were significant intra-group differences with respect to the EMC group in the variables of % body fat and balance with eyes open/closed and dynamic. Conclusion: The multicomponent training protocol including exercises with elastics performed at progressive intensity and volume over time is effective in improving body composition and balance in healthy older women.

Keywords: Physical conditioning, Elastic bands, Quality of life, Physical training.

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INTRODUCTION

There are numerous theories about why and how we age. Spirduso (2005) pointed out that "*aging*" refers to the changes that occur throughout the life of an organism, despite the fact that the rate at which they occur varies considerably between people. Currently, four premises have defined the course of aging according to Strehler (1985): a) Universal: each event linked to aging must take place to a certain extent in all people; b) Intrinsic: the reasons that lead to aging must be endogenous; c) Deleterious: the phenomena linked to the aging process are harmful; d) Progressive: the changes that lead to aging are generated gradually throughout life. Spain has one of the lowest fertility rates on the planet and considerable life expectancy at birth. These facts cause the so-called "*aging of aging*" (Limón & Ortega, 2011). The causes of the increase in life expectancy are education, the work of public health, advances in health care, the substantial decrease in fertility and the entry into old age of the generation of the "*baby boom*" (Murphy, 2017).

Regarding the physiological effects of aging on the musculoskeletal system, it is known that in sedentary people there is a pronounced decrease in muscle strength after 50 years of age, and it deepens after 60 years (Goodpaster et al ., 2001). However, the event through which people lose strength and muscle mass linked to age is called sarcopenia. Throughout life, several factors occur that facilitate its appearance: a) loss of lean mass; b) decrease in type II fibres; c) reduced blood flow; d) infiltration of connective and adipose tissue in the skeletal muscle; e) reduction of motor units; f) myofibril mismatch (Cruz-Jentoft & Sayer, 2019). On the other hand, aging leads to a decrease in bone mass and leads to skeletal weakening in older adults. With age, there is a demineralization of the bone tissue that leads to the distortion of the length of the bones of the lower limbs, as well as the narrowing of the vertebrae (Burr, 2019). Osteoporosis is a condition that arises after a disturbance in the remodelling of bone tissue, caused by the mismatch between bone resorption and bone formation. This materializes in the emergence of micro-structural disorders and especially in a decrease in bone mineral density (Kanis et al., 2019). This weakening of the bones caused by osteoporosis, added to the decrease in muscle mass and strength, leads to loss of balance during walking and increases the risk of falls (Bautista, 2008). High fall rates lead to an increase in the number of injuries, causing morbidity and mortality factors to also increase in the elderly population (Hochberg, 2008). Regarding adipose tissue, the course of aging leads to changes in the % of body fat due to multifactorial causes generated by changes in lifestyle and in the inflammatory system, genetic factors and hormonal changes (Lima et al., 2019) . It should be noted that the reduction in energy expenditure as a result of the decrease in physical activity, together with the deceleration of the basal metabolism, generates an increase in fat mass and weight throughout aging, which means that with the passage of time in a trouble doing physical activity (Cobos, 2017).

Currently, physical activity is essential for good health, in addition to being considered one of the most advantageous factors of lifestyle (Simioni et al., 2018). There are numerous demonstrated health gains in older adults, especially improvement or preservation of cardiovascular function, physical function, balance, flexibility, stability and posture, muscle mass, muscle power and strength , as well as body composition, among other aspects (Galloza et al., 2017). Following the publication "*Position Stand on Physical Activity and Exercise for Older Adults*" by the American College of Sports Medicine (ACSM), the importance of designing training programs for the maintenance and improvement of functional fitness in older adults was emphasized (AM), where exercises that work the aerobic component, strength, balance and flexibility are included, thus forming a multicomponent training program (EMC). Studies such as those by Bouaziz et al. (2016), Freiberger et al. (2012), Leite et al. (2015) and Marques et al. (2011) showed that the EMC practiced regularly presents improvements in the reduction of fat mass, increase in muscle strength, cardiovascular fitness and agility, and therefore, at the level of AM functionality.

Currently, the elastic material stands as a very valid material to carry out physical activity, since it is easy to apply and maintain, portable and inexpensive, allowing to increase, among other physical qualities, power and muscle strength (Aboodarda et al. al., 2016; Colado et al., 2018, 2020). As far as AM is concerned, studies such as the one by Flandez et al. (2020), Fritz et al. (2018) and Gargallo et al. (2018) verify the effectiveness of these devices to enhance isokinetic, isotonic and isometric muscle strength in healthy and ailing HS, for which they advise the use of this type of device in order to increase and preserve musculoskeletal fitness.

For all of the above, the purpose of this study was to analyse the effects of a multicomponent training program with some short-term elastic exercises on body composition and balance parameters in older adults. Our hypothesis is that the application of a short duration multicomponent training program using some elastic exercises will contribute to significantly improve body composition and static and dynamic balance in older adults.

MATERIAL AND METHODS

Participants

24 older adult women (mean age: 67.87 years; mean weight: 70.08 kg) were randomly assigned to two experimental groups [1] control (CG, n = 12); [2] multicomponent exercise (MCE, n = 12). All groups were homogeneous in terms of number, gender, age and weight. The initial characteristics of the participants are presented in Table 1. All the ethical considerations and the work protocols of this study were approved by the Ethics Committee of the University of Valencia (No. H1508742840440), supporting the requirements established in the Declaration of Helsinki. from 1975, revised in 2008. 24 older adult women (mean age: 67.87 years; mean weight: 70.08 kg) were randomly assigned to two experimental groups [1] control (CG, n = 12); [2] multicomponent exercise (MCE, n = 12). All groups were homogeneous in terms of number, gender, age and weight. The initial characteristics of the participants are presented in Table 1. All the ethical considerations and the work protocols of this study were approved by the Ethics Committee of the University of Valencia (No. H1508742840440), supporting the requirements established in the Declaration of Helsinki. from 1975, revised in 2008.

Table 1. Initial characteristics of the studied sample.

Characteristics	GC (*n* = 12)	GEMC (*n* = 12)
Age (years)	67.92 ± 5.68	67.83 ± 3.19
Weight (kg)	68.22 ± 8.30	71.95 ± 16.92
Height (m)	1.57 ± 0.06	1.59 ± 0.07
IMC (kg/m^2)	43.52 ± 5.24	44.98 ± 9.71
Fat mass (%)	40.49 ± 4.49	40.08 ± 7.79

Note. Data are presented as mean ± standard deviation. BMI = body mass index; CG = control group; GEMC = multicomponent training group.

Measures

The analyses of the different variables were carried out in the same municipal activity centres for the elderly in Valencia. The participants attended two weeks before the beginning of the physical intervention program, and two weeks after its conclusion to undergo the evaluations, adhering to the same interval and time period.

Size

Height was verified to the nearest 0.01 cm using a portable stadiometer (Seca T214, Hamburg, Germany).

Weight and body composition

Weight and body composition (fat mass and lean mass) were assessed using the Tanita® BF-350 bioimpedance digital scale (Tanita Corp., Tokyo, Japan). Participants were advised to: a) fast for 12 h the day before the measurement, allowing water consumption; b) avoid intense exercise 12-24 h prior to the test; c) maintain a correct position of feet, body and head when positioning on the apparatus.

Balance

This variable was analysed using three evaluation tests: a) Balance test in tandem position: the participants placed the dominant foot in front and maintained the position as long as they could. The test was scored 0 if they lasted <3 s; 1 point if they held between 3-9 seconds; 2 points if they remained in the correct position for 10 seconds; b) One-legged balance test with eyes open/closed: the participants stood with their arms extended to the sides and then lifted one foot off the ground. Time was stopped if the support foot moved; if the foot suspended in the air touched the ground; if the maximum equilibrium time established in 30 s was reached. The participants first performed the test with their eyes open and then with their eyes closed; c) Dynamic balance test by walking speed: the 4m test at maximum speed extracted from the "*Short Physical Performance Battery*" was used. (SPPB) (Guralnik et al., 1994). The participants ran 4 m at the maximum possible speed without actually running, starting the walk at a reference point located 1 m before the 4 m evaluated and ending it 1 m beyond the stipulated deceleration. Participants were allowed two attempts to familiarize themselves with the test. The best time of both attempts was recorded and coded as follows: a) <4.82 s = 4points; 4.82 – 6.20 sec = 3 points; 6.21 – 8.70 sec = 2 points; >8.70 sec = 1 point; without execution = 0 points). In all the balance measurement tests, a digital stopwatch and a record sheet were used to record the results. Likewise, prior instructions were given to all the participants so that they executed the tests in the best way.

Procedures

Training protocol

The supervised intervention program included 2 weekly sessions of 50 min to 1 hour performed on non-consecutive days (48 hours apart) for 12 weeks. Following the advice of the American College of Sports Medicine, each exercise session was divided into three phases: a) a 10-minute general warm-up; b) 35-40 minutes made up of exercise blocks for balance (static and dynamic), strength (thruster and stride), aerobic and agility (displacements modifying speed, direction and amplitude) and flexibility (active static stretching); c) a cooling phase of 10 minutes. Multi-joint exercises were performed to emphasize major and minor muscle groups (Garber et al., 2011). The participants performed the exercises in the same order. Elastic bands (TheraBand®, Akron, OH, USA) and a metronome were used as equipment.

The intensity and volume of work of the EMC group evolved progressively in each of the blocks: a) balance: the intensity increased by reducing the support points and eliminating the visual component; while the volume was increased by increasing the duration; b) strength: the participants performed 15 submaximal repetitions at moderate intensity. The level of perceived exertion on the OMNI-RES Scale for elastic bands (Colado et al., 2012) progressed from 6-7 (somewhat hard) in the first 4 weeks to 8-9 (hard) in the remaining 8 weeks. Intensity control using this method (which takes into account colour, grip width, and number of bands) has been validated in older adults (Colado et al., 2018). The number of sets per exercise progressed from 3 in the first 8 weeks to 4 sets in the remaining weeks. The speed of execution of the strength exercises was controlled by means of a metronome that marked the cadence (2 s of concentric contraction and 2 s of eccentric contraction). The participants underwent four familiarization sessions prior to the intervention to: i) select the colour, the grip width and the number of bands; ii) adapt to the rate of perceived exertion; iii) Learn the proper technique for exercises. Loads were adjusted weekly to maintain appropriate training intensities by tailoring the colour and number of elastics along with grip width. Training attendance at each session was recorded; c) aerobic and agility: the intensity was increased by increasing the speed of displacement, the amplitude of stride, as well as the number of displacements; f) flexibility: during the training protocol the same exercises and execution times were maintained. Regarding the rest time, 90 s of active rest were allowed between exercises (slow rhythmic rocking of the limbs without using the elastics) in order to increase caloric expenditure and improve the cardiovascular system. As for the break between exercises, the participants had 60 s to hydrate and dry off the sweat.

Statistical analysis

Statistical analysis was performed with commercial software (SPSS, Version 26.0; SPSS Inc., Chicago, IL). All data were reported as mean and standard deviation. The assumption of normality and homogeneity of the dependent variables was verified with the Kolmogorov–Smirnov and Levene tests, respectively. An independent samples t-test was used to determine at the intergroup level the effects of the intervention over time on the variables evaluated (% fat, tandem balance, open eyes balance, closed eyes balance and dynamic balance), and subsequently performed a related samples t-test to detect possible differences over time at the intragroup level. A confidence level of 95% was accepted (significance of $p \leq .05$). Cohen's coefficients (d value) were used as indicators of the size of the effect on intragroup evolution (trivial < 0.2; small 0.2 - 0.49; moderate 0.5 - 0.8; large > 0.8). The percentage of increase/decrease of each variable was calculated with the following formula: % = [(post-test value – pre-test value/pre-test value] x 100.

RESULTS

Twelve weeks of the EMC protocol were sufficient to cause a statistically significant positive effect or trend compared to the control group.

The independent samples T-test indicated that there were significant differences or trends between the following study variables with respect to the control group: a) tandem balance, $t(22) = 1.915$, $p = .07$; b) open eyes balance, $t(22) = 1.926$, $p = .07$; c) eyes closed balance, $t(22) = 2.107$, $p < .05$; d) dynamic equilibrium, $t(22) = -2.149$, $p < .05$. There were no statistically significant differences between groups with reference to the baseline mean values of the different dependent variables.

Table 2. Effects of the intervention on the dependent variables.

Variable	Group	Initial	Post-test	Δ%	Size effect *d*
Fat mass (%)	GC (*n* = 12)	40.44 ± 4.49	41.34 ± 4.83**+**	2.23	-0.19
	GEMC (*n* = 12)	40.08 ± 7.79	38.55 ± 7.60**+**	-3.82	0.20
Balance Tandem(s)	GC (*n* = 12)	1.75 ± 0.45	1.75 ± 0.45	0.00	0.00
	GEMC (*n* = 12)	1.92 ± 0.29	2.00 ± 0.00**^**	4.17	0.39
Balancing Eyes Open (s)	GC (*n* = 12)	20.06 ± 10.99	17.77 ± 10.79**+**	-11.42	-0.21
	GEMC (*n* = 12)	16.26 ± 9.88	25.84 ± 9.72**+^**	58.92	0.98
Balance Eyes Closed(s)	GC (*n* = 12)	4.35 ± 2.65	3.56 ± 2.34**†**	-18.16	-0.32
	GEMC (*n* = 12)	5.57 ± 5.39	9.28 ± 9.11***†**	66.61	0.49
Dynamic Balance(s)	GC (*n* = 12)	2.06 ± 0.26	2.24 ± 0.26**†**	8.74	-0.69
	GEMC (*n* = 12)	2.22 ± 0.27	2.04 ± 0.20***+**	-8.11	0.76

Note. Data are presented as mean ± standard deviation. Δ% = percentage change from pre to post-test; CG = control group; GEMC = multicomponent training group; *Significant differences between groups (p ≤ .05); +Significant intragroup differences (p ≤ .05); ^Statistically significant trend between groups (values between 0.06 and 0.12); †Statistically significant within-group trend (values between 0.06 and 0.12). Cohen's coefficients (d-value): trivial < 0.2; small 0.2 - 0.49; moderate 0.5 - 0.8; large > 0.8.

The EMC group presented the following dissimilarities or significant trends on the dependent variables over time: a) % body fat, $t(11) = 4.389$, $p < .05$; b) open eyes balance, $t(11) = -3.136$, $p < .05$; c) eyes closed balance, $t(11) = -1.938$, $p = .08$; d) dynamic equilibrium, $t(11) = 2.109$, $p = .06$. The changes in the variables analysed at different times of the study are presented in Table 2.

DISCUSSION

The main and novel finding of the present study was that the EMC executed with elastics produced improvements in the values of % body fat, static and dynamic balance. The AM of the EMC group managed to significantly reduce the % body fat compared to their previous values by 3.82%. For its part, the CG significantly increased this same parameter by 2.23%. However, no significant differences were found at the intergroup level, possibly due to the short duration of the study.

The results obtained regarding body composition coincide with those obtained by Marques et al. (2011) where the participants of the EMC group manage to reduce the % of body fat possibly due to the aerobic component that this protocol incorporated. Another investigation led by Villarreal et al. (2012) studied AM with obesity by subjecting them to a 12-week CME protocol. This research group pointed out significant differences in the % of body fat, concluding that this protocol is beneficial to improve the motor functionality of the AM due to the increase in muscle mass and reduction in fat mass. Finally, Bouaziz et al. (2016) in their systematic review concludes that the EMC facilitates functionality and health, in addition to generating improvements at the metabolic level in the AM.

Regarding static balance, improvements were achieved in this study. If the effects of training in the EMC group are compared, a trend towards improvement of 4.17% is observed in the tandem balance test with respect to the CG. On the other hand, the balance test with open eyes produced a significant difference at the intragroup level (EMC, 58.92% improvement) and a tendency to improve with respect to the CG (11.42% worse). Regarding balance with eyes closed, the EMC improved by 66.61%, establishing a significant difference with respect to the CG and a tendency to improve at the intragroup level. The CG worsens 18.16%, generating a negative trend with respect to the previous measure.

To date, studies such as Toraman, Erman & Agyar (2004) in which a 9-week MA CME program was applied support our results of improved balance. Another investigation that supports our findings is that of Freiberger and collaborators (2012). In this study, an EMC protocol with AM was applied where the balance was analysed in the short and long term, finding significant differences. Freiberger and collaborators (2012) evaluated the incidence on the reduction of falls, however, they could not point out significant dissimilarities. In contrast to the findings of the previous study on falls, the research by Cho et al. (2018) applied an EMC protocol for 8 weeks in AM, achieving significant effects on balance at the intragroup level, as in our study. Thanks to this improvement, Cho et al. (2018) achieved a significant difference by reducing the level of risk of falling from high to low in 22 of the 53 participants.

In reference to dynamic balance, our study reflects that the EMC group reduced the time invested in running the 4-meter walk at maximum speed by 8.11%, reaching a significant difference at the intragroup and intergroup level compared to the CG. This worsened by 8.74%, reaching a worsening trend at the intragroup level.

In the study carried out by Leite et al. (2015) the dynamic balance was evaluated through the 7 m walk test at maximum speed. As in our research, Leite et al. (2015) managed to record improvement results after a

12-week EMC protocol. Another investigation led by Forte et al. (2013) analysed the dynamic balance of the participants through a 10 m walk test at maximum speed. The results after 12 weeks of intervention applying EMC generated a significant effect of improvement in dynamic balance, supporting our thesis. Finally, the study by Ferreira et al. (2018) supports our findings regarding dynamic equilibrium. Ferrera et al. (2018) evaluated the dynamic balance in AM after 12 weeks of EMC intervention through the 4 m walk test at maximum speed with a round trip. In summary, a short-term supervised CME program that includes elastics has a positive impact on the walking speed of the AM, which facilitates the improvement of their functionality and quality of life.

Finally, the present investigation has some limitations that must be taken into account when trying to draw conclusions based on the evidence. The results presented in this study are specific to healthy older women, so they should not be extrapolated to other populations. In addition, the small sample size of the groups was another limitation. Lastly, we did not control or assess daily physical activity levels or nutritional intake, although our participants were asked to maintain their usual daily activities throughout the study period and not to change their nutritional habits. Future studies should be carried out applying and comparing other physical exercise protocols.

CONCLUSIONS

Our results show that a 12-week progressive EMC training protocol using elastics can significantly improve short-term body composition in healthy AMs by decreasing % body fat, which could improve their metabolic health. These results reveal a possible dose-response relationship, although we found no significant differences between groups. More research is warranted in this regard. In addition, we observed a significant improvement in the balance tests with eyes closed and eyes open, along with a trend towards improvement in the tandem balance test. Due to this, these improvements can be positively linked with the prevention of the risk of falls, which would avoid possible injuries and morbidities in the MA. Finally, this study establishes significant positive differences in the dynamic balance of healthy AMs by improving the recorded times. However, the benefits previously reported for static balance in conjunction with an improvement in walking speed have a positive correlation with respect to an increase in longevity and quality of life of people.

AUTHOR CONTRIBUTIONS

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

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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

Contraceptive practices and contraceptive counselling in high-performance Portuguese athletes

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ABSTRACT

We present an observational, prospective, descriptive study of answers collected through an online self-assessment questionnaire in High Performance Portuguese Athletes aged 18 years old or over. The main objective was to evaluate contraceptive practices, menstrual patterns and contraceptive counselling in these athletes. Overall, 115 women aged between 18 and 39 years were studied, from 18 different sports. In our sample, most athletes used some type of contraception. Most believed that they had a better performance after menstruation and that starting contraception did not interfere with their performance. However, a high number of athletes believes that contraceptives are contraindicated for sports.

Keywords: Sport medicine, Performance analysis of sport, Amenorrhea, Sports health, Sports performance, Contraception.

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INTRODUCTION

During the last decades there has been an increase in the number of women practicing elite sports. The rate of women competing in the Olympic Games has increased from less than 10% at the start of the modern Olympic Games in 1894 to almost 49% in Tokyo 2020 (Committee., 2021). This can be related to the emancipation of women during the 20th century and the development and investment in women's professional sport (International Working Group on Women and Sport, 2007) (Forsyth J, 2018). However, scientific research has not grown in parallel with the exponential increase in female participation, and many of the studies carried out in men should not be extrapolated directly to women, given the anatomical, physiological and endocrinological differences between the sexes (Costello JT, 2014) (Emmonds S, 2019) (Forsyth J, 2018) (Sheel, 2016) (McNulty KL, 2020) (Carole Castanier, 2021).

The menstrual cycle can be different in elite athletes. Studies have shown controversial results regarding the hormonal effects of the menstrual cycle on sports performance, and most are based on small samples (Burrows M, 2007). Multiple mechanisms have been suggested. During the normal cycle (McNulty KL, 2020) oestrogens can promote an anabolic effect on the skeletal muscle, on cellular glycogen storage increase and on fat utilization increase (Baltgalvis KA, 2010) (Lowe DA, 2010) (Isacco L, 2017) while progesterone can act centrally at hypothalamic sites and at the peripheral level by chemosensitivity during the luteal phase (Behan M, 2003) (Bayliss & Millhorn, 1992), with an effect on the ventilatory drive (Duke, JW., 2017), by stimulating hyperventilation at rest and during exercise. Additionally, both oestrogens and progesterone act as neurosteroids, that can cross the blood-brain barrier and thus promote effects on maximal neuromuscular performance (Tenan, MS., 2017).

On the other hand, even in female athletes with regular cycles, the follicular phase can be prolonged with a shortened or absent luteal phase, secondary to a Luteinizing Hormone (LH) deficit that induces insufficient progesterone production (De Souza, 2003). Additionally, a significant number of athletes present cycle changes that vary between oligomenorrhea and amenorrhea. The reason for amenorrhea is probably multifactorial, being directly linked to the high load of physical exercise and/or insufficient food intake. The so-called Relative Energy Deficiency in Sport (RED-S) suggests that menstrual irregularities presented by athletes are not due to sport itself, but a consequence of an energy imbalance between what they consume and what they spend during training and competitions. In this way, secondary amenorrhea is not considered physiological and must be addressed and treated (Mountjoy M, 2018). Factors that may contribute are: 1) excessive secretion of endorphins, including high opioid tone that inhibits the hypothalamic-pituitary-gonadal axis; 2) insufficient fat mass to prevent the transformation of androgens into oestrogens with a parallel decrease in leptin; and 3) excessive prolactin secretion (Carole Castanier, 2021). Menstrual dysfunction in female athletes and late onset of menarche in adolescents have been associated with low Body Mass Index (BMI), which can be modulated by training (Brook, E., 2019) (Thein-Nissenbaum & Hammer, 2017). Most studies have reported significantly lower free fat mass in female athletes with amenorrhea compared to women with normal menstrual cycles (Tornberg, et al., 2017) (Ackerman KE, 2012) (Carlberg KA, 1983).

In amenorrheic athletes, a study has showed that athletes with an energy deficit had a regression in their velocity performance when compared to athletes with a normal menstrual cycle (Vanheest JL, 2014). However, no variations in jumping or speed abilities was found (Julian R, 2017) (Tounsi M, 2018).

The use of hormonal contraception (HC) among female athletes seems to be similar to that of the general population (Burrows M, 2007), between 47-57% (Martin D, 2018) (Larsen B, 2020) (Oxfeldt M, 2020) and up to 50% of elite athletes use oral contraceptives (OC) (Hagmar M, 2009).

HC has been an option for some athletes who want to avoid adverse effects related with eumenorrheic cycles, such as pelvic pain, oedema, headache, hypermenorrhoea or to eliminate an unpredictable menstruation. The athletic population has reported to strategically manipulate the time of withdrawal bleeding that occurs during the 7-day break (Martin D, 2018) (Schaumberg MA, 2017).

Despite the high use of HC in the athlete population (Martin D, 2018), its effects and implications on sports performance, namely on muscular function, aerobic and anaerobic capacity, are poorly understood, inconsistent and controversial (Sarwar R, 1996) (Rechichi C, 1996) (Giacomoni M, 2000). Considering that the fluctuation of steroid hormones can be a factor that interferes with performance and exercise capacity, it is imperative to understand the effect of administration of different types of HC (Burrows M, 2007). Some authors have shown that OC resulted in reduced peak exercise capacity and decreased maximal oxygen uptake when compared to non-hormonal contraceptives (Casazza GA, 2002) (Lebrun CM, 2003). No differences in maximal force-generating or jumping ability were seen with the use of combined oral contraceptives (COC) (Lebrun CM, 2003) (Julian R, 2017) (Tounsi M, 2018) (Thompson B, 2020) (Myllyaho, et al., 2021).

A 2020 meta-analysis concluded that COC users, compared to eumenorrheic women, present a slightly lower sports performance (Elliot-Sale KJ, 2020). In fact, the endogenous hormone profile of COC users is comparable to the profile observed during the early follicular phase of the menstrual cycle (Elliott KJ, 2005). An analysis indicated that sports performance was relatively consistent across the cycle under HC (Elliot-Sale KJ, 2020). The endogenous hormonal profile is primarily responsible for sports performance compared to exogenous hormone supplementation (Elliot-Sale KJ, 2020).

The World Anti-Doping Agency (WADA) has officially implemented the Athlete Biological Passport since 2009 to monitor certain biomarkers over time (Available online, n.d.). Hormonal contraceptives can have a major impact on the female steroid profile, so their use should always be questioned in the doping control forms (Schulze JJ, 2014). The ratio of Testosterone/Epitestosterone glucuronides makes possible to distinguish between exogenous and endogenous testosterone, with epitestosterone being one of the most fluctuating biomarkers (Mullen, et al., 2016) (Schulze, et al., 2021).

Objective

The main objective of this study was to evaluate the contraceptive practices of high-performance female athletes. The secondary objectives were to assess menstrual patterns and contraceptive effects that could possibly change the athletes' physical performance and to evaluate the type of contraception counselling given to these athletes.

METHODS AND MATERIALS

This was an observational, prospective and descriptive study of answers collected through an online questionnaire completed between May and October 2021 among Portuguese Elite Athletes aged 18 or over. The questionnaire was anonymous and confidential and was carried out through a link sent by email through the different Sports Federations of Portugal: Athletics, Badminton, Basketball, Canoeing, Gymnastics, Handball, Judo, Karate, Orienteering, Padel, Roller Hockey, Skating, Football, Swimming, Tennis, Triathlon and Volleyball.

The questionnaire was divided into 5 sections: 1) individual characteristics and menstrual pattern of the Athlete, 2) type of sports practice, 3) contraceptive use and the perception of its effects, 4) contraception and physical performance, and 5) contraceptive counselling. The following were evaluated: age, weight, height, age at menarche, duration and regularity of menstruation, previous amenorrhea (defined as absence of menstruation not associated with contraceptives or pregnancy for more than 6 months), degree of dysmenorrhea and parity. In section 2, sports habits were questioned: sports modality, weekly training hours and age at which sports practicing started. Regarding contraceptive practices (section 3), questions were asked about the contraceptive methods used, duration of use, reason for starting contraception and any beneficial or adverse effects felt. In section 4, the questions were about whether menstruation or the initiation of contraception affected the athletes' physical performance. Finally, we addressed issues related to contraceptive counselling during sports practice.

A descriptive analysis of the data was performed, with tables of absolute and relative frequencies. All questionnaires received were used, excluding 7 (1 no consent, 6 under 18 years old).

RESULTS

Individual characteristics and menstrual pattern of the athlete

A total of 115 women aged between 18 and 39 years were studied (Table 1), with a mean age of 22.2 (SD ± 4.03) years. Only 2 women were not nulliparous (1.7%). The athletes' height varied between 153 and 193cm, with a mean of 168.5cm (SD ± 8.09), while the athletes' weight ranged between 43 and 120 kg, with an average of 63.7 kg (SD ± 11.05). The mean BMI was 21.86 kg/m^2, with a minimum value of 16 and a maximum of 41 (SD ± 2.96; median 20).

Table 1. The individual characteristics of the athletes.

	Minimum	Maximum	Median	Mean	Standard Deviation
Age (years)	18	39	21	22.2	4.03
Height (cm)	153	193	168	168.5	8.09
Weight (kg)	43	120	62	63.7	11.05
BMI	16	41	20	21.86	2.96
Menarche age	10	18	13	13.04	1.38

Literary qualifications were College Education (n = 57; 49.6%), High-School (n = 55; 47.8%); 3rd cycle of schooling (n = 1; 0.9%).

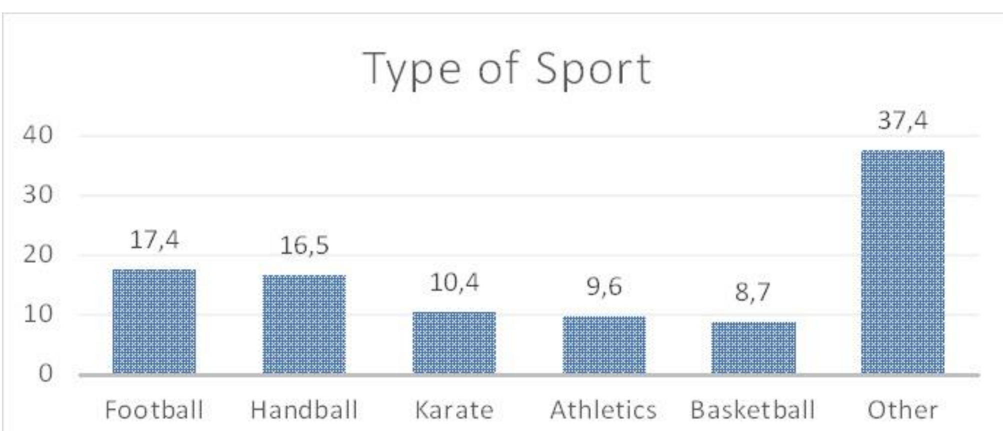


Figure 1. Distribution of athletes by modalities (%).

Most athletes practiced individual sports (n = 59, 51%). The modalities of the athletes studied were football (n = 20; 17.4%); handball (n = 19; 16.5%), karate (n = 12; 10.4%), athletics (n = 11; 9.6%), basketball (n = 10; 8.7%) and others (skating n = 8; volleyball n = 7, judo n = 6, gymnastics n = 5, badminton n = 4, canoeing n = 3, padel n = 3, roller hockey n = 2, swimming n = 2, orienteering n = 1, tennis n =1 and triathlon n = 1) (Figure 1).

Age at menarche ranged between 10 and 18 years, with a mean of 13.04 (SD ± 1.38). 14 athletes (12.2%) had menarche with 15 years old or above. The mean duration of menstruation was 5.02 days (SD ± 3.27). The maximum interval without menstruating was 48 months, mean of 3.48 (SD ± 6.38; median 2).

Overall, 15 athletes (13%) had irregular cycles. Of these, 40% (n = 6) had a BMI ≤ 20kg/m^2. On the other hand, 12 reported having had periods of amenorrhea (10.4%), half (n = 6) of them had a BMI ≤ 20kg/m^2.

In this sample, 17 women (14.8%) play sports where the fat mass is usually low (gymnastics, athletics and triathlon). In this group, 17.6% (n = 3) did not have regular cycles (vs. 12.1%; n = 12/98) and 29.4% (n = 5) had had at least one episode of amenorrhea (vs. 7.1% n = 7/98).

Dysmenorrhea was classified between 0 and 10. The mean was 3.14 (SD ± 2.48).

Sports practice

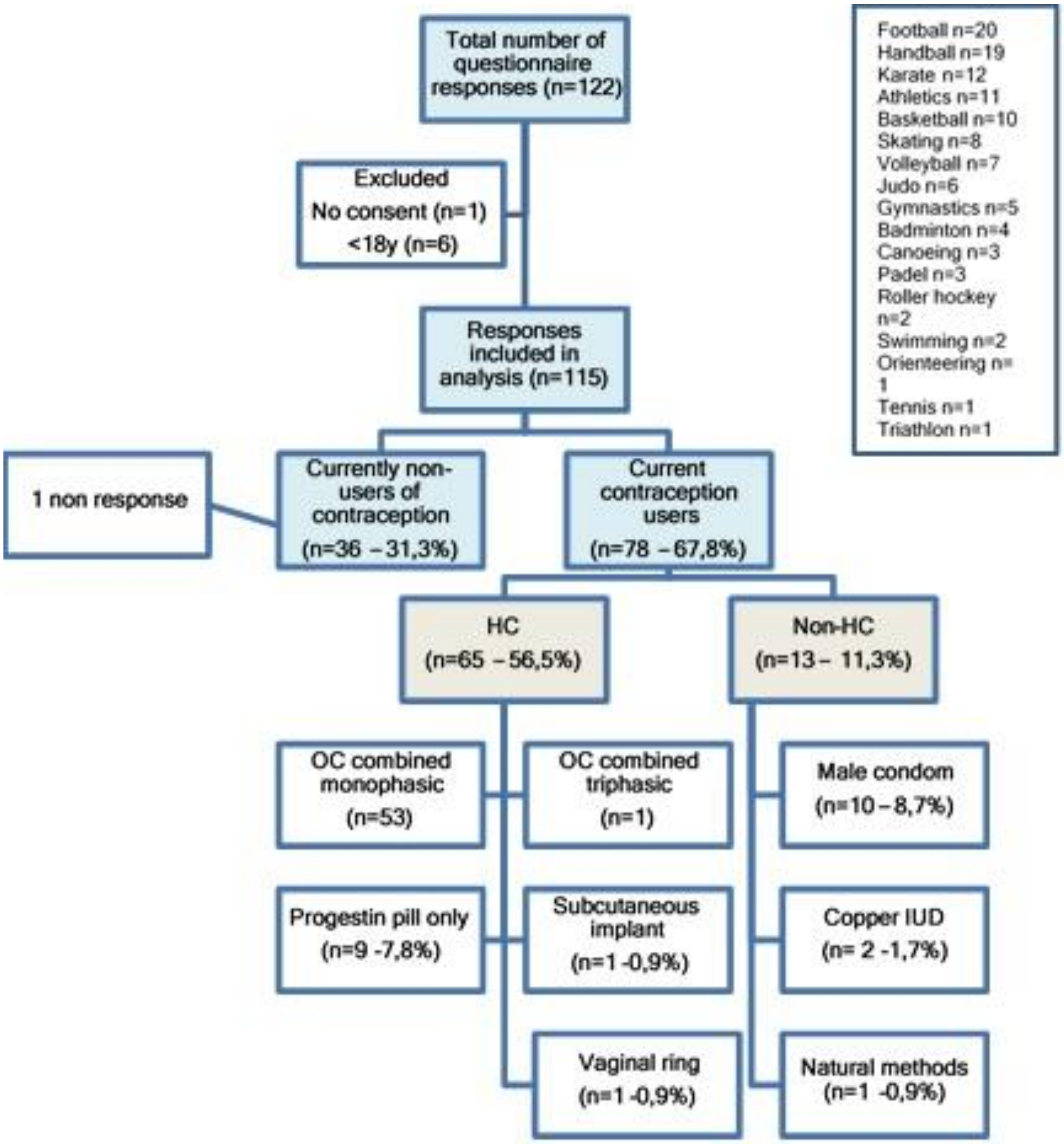
The average number of weekly hours of training was 12.35 (SD ± 7.19; median 12). 36.5% of the athletes trained 6 days a week (n = 42), followed by 5 (n = 25; 21.7%), 4 (n = 18; 15.7%), 7 (n = 16; 13 .9%), 3 (n = 12; 10.4%) and 2 athletes trained only 2 days a week (1.7%). On average, athletes were practicing the elite sport for 9.1 years (SD ± 4.8, median 8). Training was classified as resistance, strength, speed, flexibility or mixed training. Mixed training was the most frequent (n = 87; 75.7%), followed by resistance training (n = 13; 11.3%), strength (n = 10; 8.7%), speed (n = 4; 3.5%) and flexibility (n = 1; 0.9%).

Contraceptive use and its effects

We found that 67.8% (n = 78) of the athletes used a contraceptive method, 65 of which (83.3%) used hormonal contraception, 10 used a male condom, 2 a copper intrauterine device and 1 natural methods (Figure 2). None of the athletes used the Levonorgestrel Intrauterine System.

The use of hormonal contraception was distributed as follows: 53 monophasic combined pill (2 in continuous administration), 1 triphasic, 1 vaginal ring, 9 pill with progestin only, and 1 subcutaneous implant of Etonogestrel. In the case of combined pills, the Etinilestradiol dosage ranged from 0.02 to 0.03 mcg and the progestin was: Gestodene (n = 22), Drospirenone (n = 11), Dienogeste (n = 13), Chloromadinone (n = 3), Levonorgestrel (n = 1) and Nomegestrol Acetate (n = 1).

The main reason for starting contraception was to avoid pregnancy (n = 36; 45.6%), followed by acne treatment (n = 15; 19%), dysmenorrhea control (n = 12; 15.1%), menstrual cycle regulation (n = 7; 8.9%), menstrual cycle monitoring for competitions (n = 2; 2.5%), to reduce menstrual flow (n = 2; 2.5%), treatment of anaemia (n = 1; 1.3%) and treatment of polycystic ovarian syndrome (n = 1; 1.3%) (Figure 3).



Note. IUD, Intrauterine Device; OC, Oral Contraceptive; HC, Hormonal Contraception.

Figure 2. The prevalence of type and delivery method of contraceptives used and the prevalence of non-contraception use.

The mean duration of contraceptive use was 43.9 months (SD ± 54.6; median 24). Overall, around 80% of the athletes reported changes with contraception: reduced or absence menstruation (n = 36; 45.6%), reduction in dysmenorrhea (n = 29; 36.7%), improvement of acne (n = 16; 20, 3%), weight gain (n = 9; 11.4%), increased dysmenorrhea (n = 6; 7.6%), onset of headache (n = 2), increased amount of menstruation (n = 1; 1.3%), and breast tenderness (n = 1; 1.3%).

Around 20% of the athletes (n = 23/115) had already stopped taking a contraceptive method, mostly because of body weight gain (n = 4), mood changes (n = 2), feeling of a lower sports performance (n = 2), pregnancy or pregnancy attempt (n = 2), menstrual irregularities or spotting (n = 2), and other unspecified changes (n = 7).

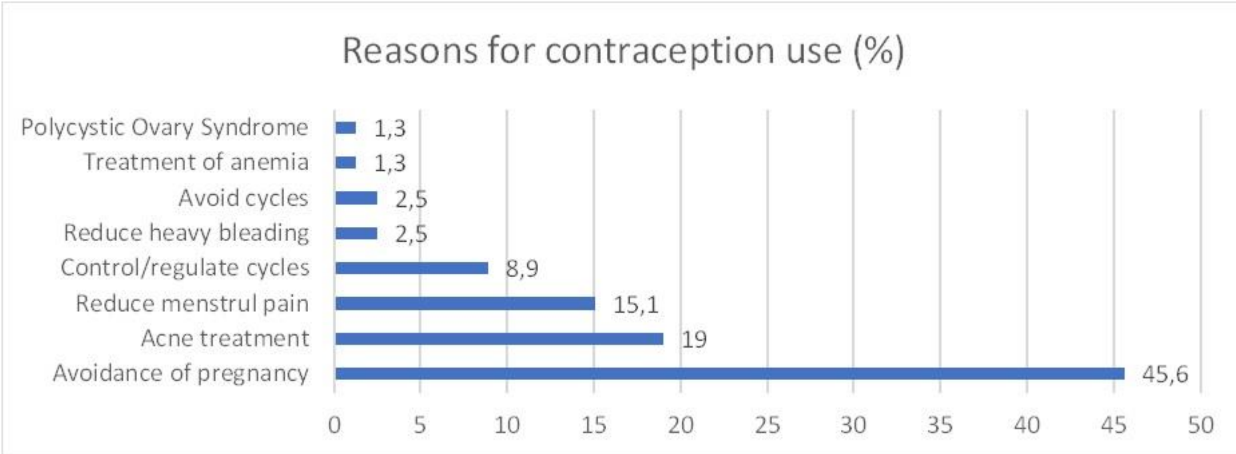
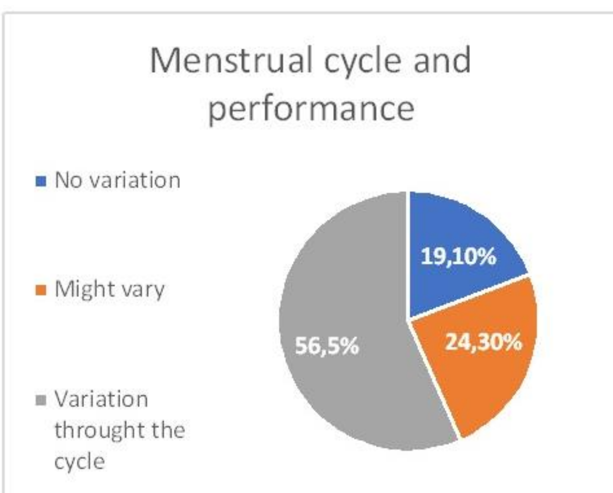


Figure 3. Reasons for contraception use in current users (%), (n = 78 – 2 non responders).

Contraception and physical performance

51.3% of the athletes felt that menstruation did not interfere with their sports practice (n = 59/115), 42.6% reported a negative interference (n = 49/115) and 5.2% a positive interference (n = 6 /115). 56.5% of the athletes reported that physical performance changes throughout the menstrual cycle (n = 65), 24.3% (n = 28) reported that it might change and 19.1% (n = 22) reported that it does not (Figure 4) Of those who reported that performance changed throughout the menstrual cycle, most felt a higher performance after menstruation (n = 40/65; 61.5%), followed by greater performance before menstruation (n = 14/65; 21.5%) and finally during menstruation (n = 12/65; 18.4%) (Figure 4). On the other hand, the time of the menstrual cycle in which athletes feel most tired is during menstruation (n = 59/115; 51.3%), followed by the days before menstruation (n = 28/115; 24.3 %). 23.5% (n = 27/115) of the athletes reported that fatigue was not phase related. Regarding the interference of the beginning of contraception with sports performance: most athletes (n = 59/79; 74.6%) reported that it did not affect their sports performance, 9 revealed that it was positively related (11.4%), and only 4 had a negative perception (5.1%) (3 did not respond).



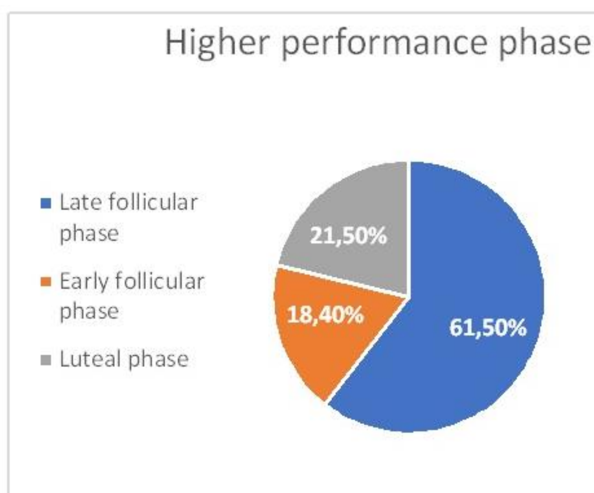


Figure 4. Percentage respondents for changes of performance throughout menstrual cycle and better menstrual phase for greater performance.

Near 27% (n = 31) answered that contraceptives were contraindicated for practicing sports and almost half (n = 55; 47.8%) said that they did not know. 25.2% of athletes (n = 29) reported that contraceptives do not cause any changes.

Contraceptive counselling

51.3% of the athletes (n = 59) didn't have any contraceptive advice, 32.2% (n = 37) received some kind of and 16.5% (n = 19) did not remember. Of the athletes who received counselling, most were given by a gynaecologist (n = 23), followed by a family doctor (n = 5), friends (n = 3), family (n = 3), Federation doctor (n = 1), coach (n = 1) or other (n = 1). Most athletes never discussed the topic "*contraception*" with their coach (n = 92; 80% vs. n = 19; 16.5%). Most coaches were male (n = 93; 80.1%).

DISCUSSION

The main goal of this study was to evaluate the contraceptive practices and contraceptive advice of high-performance female athletes. It was also sought to assess menstrual patterns and to relate the effects of contraceptives to possible changes in the athletes' physical performance. The study was based on an anonymous survey that was sent to high-performance athletes through Portuguese Sports Federations. All data was provided by the athletes, reflecting their personal perceptions and experiences. The results were compared with data from the literature. There are other studies that also used questionnaires to investigate changes in performance and negative effects related to the menstrual cycle and they have reported consistent results (Martin D, 2018) (Kishali NF, 2006) (Brown N, 2021) (Bruinvels, et al., 2021). In 2019, the number of high-performance women practitioners in Portugal was 257 (Lima, 2021). Our study managed to collect a total of 115 responses, which may represent a significant and representative sample of high-performance athletes in Portugal. We found that 87% of the athletes menstruate regularly, a similar result found in the study by Mendes Coutinho et al (83%). (Coutinho F, 2021). We found that around 10% of the athletes reported having had amenorrhea and this rate was slightly higher than the prevalence of oligomenorrhea/amenorrhea in the general population, which is between 2 to 5% (Nattiv A, 1994) (Oxfeldt M, 2020) (Torstveit MK, 2005). In athletes, the prevalence of these changes, particularly of amenorrhea, can vary between 3.4 and 70%, with the highest prevalence being seen in sports where the fat mass is low, such as gymnastics or long-distance running (Nattiv A, 1994). (Oxfeldt M, 2020) (Torstveit MK, 2005). A study based on an online questionnaire in a similar sample concluded that athletes with low energy reserves had a higher risk of menstrual dysfunction and lower physical performance (Ackerman, et al., 2019). In our study, 17 athletes were practicing sports where the fat mass is low (gymnastics, athletics and triathlon). Of these, three did not menstruate every month (17.6%) and five reported previous episodes of amenorrhea (29.4%). These rates are slightly higher than the frequency found for all athletes included in the study (17.6% vs. 13%; 29.4% vs. 7.1%, respectively).

We also found that less than half of the women who did not menstruate every month were underweight, which suggests that BMI does not appear to be the only factor responsible for menstrual irregularities. It was found that 12.2% of athletes had late menarche (> 14 years), a rate comparable to a Portuguese study carried out with non-athlete adolescents (12.2% vs. 11.8%) (Marques, 2017). More than half of the athletes reported that physical performance changes during the menstrual cycle. The results of a systematic review and meta-analysis indicated that sports performance may be trivially reduced during the early follicular face (from the 1st to the 5th day of the menstrual cycle), compared to the other phases (McNulty KL, 2020); the results obtained in our study are in agreement, given that only 18.4% of the athletes reported better sports performance during menstruation and that half felt that the menstruation phase is the time in which they felt most tired (51.3%). These results are similar to the study by Coutinho et al. where they reported that about

40% of the athletes felt they had less energy during menses (Coutinho F, 2021). However, Solli et al. reported that most athletes perceive the days before menstruation as the worst phase of the menstrual cycle for performance (Solli GS, 2020). These interpretations should be cautious, since they are the results of a subjective feeling of the athletes and therefore, given the limited evidence, no general recommendations can be made about sports performance throughout the menstrual cycle (McNulty KL, 2020).

Solli et al. reported that the time after menstruation was when the athletes reported the best performance and fitness (Solli GS, 2020), while Bambaeichi et al (E Bambaeichi, 2004) found that the ovulatory phase was the best. Our study was in agreement with these data, in which more than half of the women (61.5%) reported higher performance after menstruation.

Nonetheless, other studies did not find any changes in performance between menstrual cycle phases (Casazza GA, 2002) (Elliott KJ, 2003) (Janse de Jonge, X. 2012).

In a study with 430 athletes, 77% of elite athletes had no hormonal effects during the menstrual cycle, including pain (abdominal/lower back), cramping (abdominal) and headache/migraine (Martin D, 2018). Between 31.7 and 54% of women stated that their menstrual cycle impacts upon their training and performance (Bruinvels G, 2016). Almost 75% of the athletes denied any negative influence with the initiation of contraception and about 10% reported that pill increased physical performance, while only 5% reported that the initiation of contraception negatively affected their performance. These data are similar to those described by Coutinho et al. (Coutinho F, 2021).

About 20 to 70% of elite athletes in the world use HC, with a significant variation depending on the country and modality (Oxfeldt M, 2020) (Cheng, J. 2020) (Larsen B, 2020) (Martin D, 2018). In a recent study, nearly half of the population studied did not have an eumenorrheic menstrual cycle (Martin D, 2018). Of these, 68% of the athletes were users of combined HC (Martin D, 2018), a lower rate than what we found (83.3%).

In this study 68.7% used some type of contraceptive, slightly higher than that recorded in Portugal in 2020 (68.7% vs. 61%) (European Contraception Policy Atlas - Portugal, 2021), but similar to the 71,5% found in another (Coutinho F, 2021). In our study, 83.3% of contraceptive users used HC, and of these, 84.6% used combined hormonal contraception. This is in agreement with other studies where the combined pill was preferred over the progestin-only pill (Oxfeldt M, 2020) (Larsen B, 2020) (Martin D, 2018) (Coutinho F, 2021). Long-acting reversible contraceptives are contraceptive options with little use among female athletes (Coutinho F, 2021), as was also seen in our sample.

It has been reported that the vast majority of COC users deliberately manipulate the time, frequency and amount of menstruation, for reasons of convenience, sports competitions, special events or holidays (Oxfeldt M, 2020) (Martin D, 2018) (Schaumberg MA, 2017).

However, in this study, only 8.9% used contraception with the primary objective of regularizing their menstrual cycle and only 2 athletes use contraception to monitor and model the menstrual cycle for competitions.

The most common adverse effects reported after initiation of hormonal contraception were increased body weight and mood changes, both of which can affect performance (Martin D, 2018). In our study, almost 12% of the athletes reported weight gain.

A prospective study of low-potency progestin COC and androgenicity suggested a causal link between COC administration and weight gain (Notelovitz M, 1987). This weight gain can be harmful to the performance of athletes in sports where weight gain is relevant, whether for dynamic reasons (e.g. athletics), aesthetic reasons (e.g. gymnastics), or because body weight determines a competition category (Notelovitz M, 1987) (Ex: rowing, weightlifting, judo, boxing) (Notelovitz M, 1987). Another study in inactive women revealed no differences in body weight after initiation of monophasic COC (Tantbirojn P, 2002). Rickenlund et al. demonstrated that endurance athletes who used the monophasic pill for 10 months showed a significant increase in weight and fat mass, however only in athletes with previous oligomenorrhea or amenorrhea, associated with a decrease in ovarian androgens and an increase in bone mineral density (Rickenlund, et al., 2004).

Most of the athletes received contraceptive counselling from a physician, as in the study by Coutinho et al. (Coutinho F, 2021).

There are some limitations of this study: 1) despite including a large number of elite athletes in Portugal, the sample is small and there is a large inter-individual variation, despite including almost half of Portuguese high-performance athletes, 2) the comparisons are made between athletes from different modalities with different types of training and different body weights; 3) the performance evaluation is based on the athletes' perception and not by the evaluation of physiological parameters, 4) the performance evaluation and the relation with the menstrual cycle phase is not based on laboratory criteria, and 5) great diversity of combined compounds with different doses and types of oestrogens and progestins.

CONCLUSION

In our sample, about 70% of the athletes used some type of contraception, and the combined oral contraception was the most frequently used. The main reason for its use was to avoid pregnancy and acne treatment. Around 13% do not menstruate regularly and almost 11% of them have had previous periods of amenorrhea, with a higher rate among athletes of sports where fat mass is usually low. More than half of the athletes revealed that menstruation does not interfere with their sports practice. Of those who reported changes, almost half reported that menstruation negatively affected their performance. On the other hand, most felt that menstrual cycle phase is related with their physical performance and that the late follicular phase was the best time for performance. In most athletes, starting contraception did not affect their sports performance.

AUTHOR CONTRIBUTIONS

Inês Margarida Neves Gomes: Idea/Concept, Design, Control/Supervision, Data Collection and/or Processing, Analysis and/or Interpretation, Literature Review, Critical Review, References and Fundings. Alexandra Ruivo Coelho: Literature Review, Writing the Article, Critical Review. José Luís Bento Lino Metello: Control/Supervision, Writing the Article, Critical Review.

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DISCLOSURE STATEMENT

This study was approved by the ethics committee.

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SCIENTIFIC JOURNAL OF SPORT AND PERFORMANCE

ORIGINAL ARTICLE

Study of VO_{2max} and body composition in trained soldiers of the army special operations unit

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ABSTRACT

The objective of this article was to establish comparisons between different special operations units of the army. 91 male subjects (mean ± Standard deviation; age: 33.05 ± 3.28 years; height: 1.77 ± 1.37 m; body weight 79.02 ± 1.59 kg), divided into 4 groups (mountain, diving, UEO and mobility), were evaluated through body composition and stress tests. A bioimpedance test was carried out to determine the different tissues and an incremental treadmill stress test with a gas analyser to establish the different physiological parameters. The results showed significant differences in terms of heart rate (HR) in the different thresholds (ventilatory threshold 1, ventilatory threshold 2 and maximum oxygen consumption) and in the speed reached in these ($p < .05$). On the other hand, with respect to body composition (muscle mass weight, % fat mass and fat weight), no significant differences were observed between the different groups analysed ($p > .05$).
Keywords: Performance analysis of sport, Sport medicine, Army, VO_{2max}, Body composition.

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INTRODUCTION

Physical analysis constitutes a fundamental part as the basis for sports training and performance to achieve various objectives (Dyrstad et al., 2006; Delextrat & Cohen, 2008; Courel-Ibáñez & Herrera-Gálvez, 2020). In this sense, for decades, some researchers have separated different components of physical fitness related to health and performance (Pate, 1983; Garber et al., 2011; Knapik et al., 2017; Proyer et al., 2018). Recently, in the sports field, all kinds of evaluations and tests have been included to establish parameters and aptitudes that favor an improvement in performance and, consequently, in sports success according to the characteristics and demands of the sport itself (Lidor et al., 2009; Ranković et al., 2010; Bujnovsky et al., 2019; Sarmento et al., 2014; Tabacchi et al., 2019).

There are also other areas in which tests, assessments and evaluations of physical fitness are used to establish certain requirements for access and improvement of their physical capacity, as is the case of the military (Williamson et al., 2009; J. J. Knapik et al., 2009; Knapik et al., 2017; Draicchio et al., 2020). Traditionally, physical fitness has been considered a critical element in the success of special operations because the demands of the tasks to which they are subjected require a high level of effort (McCaig & Gooderson, 1986; Friedl et al., 2000; Hoyt et al., 2006). These fitness and fitness levels are not only necessary for health, but also for specific military tasks and injury prevention (Knapik et al., 2017). The importance of evaluation and physical fitness in the military has shown, in previous operational and experimental research, how soldiers with better physical conditions and aptitudes exhibit higher levels of performance in real or simulated military tasks (J. Knapik et al., 1990; Rayson & Holliman, 2000).

In this sense, the objective of this article is to compare body composition and the different physiological variables obtained in stress tests and analyze them according to the physiological requirements and demands required by the activities in which they are specialized.

MATERIAL AND METHODS

Participants

A total of 91 subjects (mean ± Standard deviation; age: 33.05 ± 3.28 years; height: 1.77 ± 1.37 m; body weight 79.02 ± 1.59 kg) divided into 4 groups participated in the present study. These groups are made up of: 37 subjects from the mobility group, 30 mountain subjects, 11 diving subjects and 13 from the group of Special Operations Units (UOE). Military women, due to their small number of participants (n = 1), are not represented in all the operational groups analyzed. Separated by groups, Table 1 presents the characteristics of each group.

Table 1. Characteristics of the groups (Mountain, dive, UOE, mobility).

Group	Age (years) (Mean ± SD)	Height (cm) (Mean ± SD)	Weight (kg) (Mean ± SD)
Mountain	31.4 ± 6.63	176.36 ± 5.31	77.30 ± 8.98
Dive	33.64 ± 9.38	175.82 ± 4.45	81.10 ± 7.80
UOE	37.38 ± 5.95	178.92 ± 5.28	79.15 ± 8.00
Mobility	29.81± 5.75	176.65 ± 5.87	78.53 ± 9.20

It is a sample with a high level of physical condition, with a preparation and daily training program oriented to the demands of their corresponding activities. Said physical condition has been determined through factorial studies that provide construction validity for the concept of physical condition (Knapik et al., 2006). They train 20 hours a week divided into maneuvers and practices. The activities they carry out daily are determined according to the demands and preparation required by the different special operations entrusted to each of the groups (i.e., strength training, resistance, agility, dexterity).

Design

A prospective observational pilot study of a single cohort without follow-up was conducted. The study was carried out with the participation of the Technology-Based Company of the University of Alicante, Kinetic Performance.

Procedure

The control of the tests was carried out in Alicante in the year 2021. The participants were instructed to carry out the tests, which were developed under controlled environmental conditions. The tests were carried out at different times and in different months. During previous weeks, several sessions were held with the different ranges and study participants in order to report on the development of the intervention and its duration.

Measures

Anthropometry

The anthropometric study was carried out using a segmental multifrequency DSM-BIA body composition analyzer (InBody 270) and weight, fat percentage, muscle mass percentage, residual mass percentage, amount of water stored and symmetries in all body zones were obtained.

Effort test

The stress test was performed with a gas analyzer on the Technogym Excite 500 treadmill. Polar H9 heart rate bands were used for HR monitoring.

Statistic analysis

A descriptive analysis (mean and standard deviation) was used using the SPSS 25.0 program (SPSS Inc., Chicago, IL, USA). A robust ANOVA test was performed using the Brown-Forsythe and Welch tests, carrying out a posteriori (post-hoc) comparison to determine more specific significant differences between groups. The level of significance was set at $p < .05$.

RESULTS

Between the different groups of special operations compared, there are no significant differences in terms of muscle mass, fat and % of fat mass ($p > .05$). Figure 1 shows the results regarding the body composition of each of the groups. The group with the highest muscle mass (kg) is the diving group, while the group with the lowest body fat is the mountain group, but without significant differences in all the parameters analyzed ($p > .05$).

Regarding the different thresholds used (aerobic, anaerobic and maximum oxygen consumption), there are significant differences with respect to the speed reached (Km/h) in the stress tests ($p < .05$). There are also significant differences in heart rate (HR) for the aerobic and anaerobic thresholds ($p < .05$), while the same does not occur in the HR obtained at maximum oxygen consumption or VO_2max ($p > .05$). In figures 1 and 2, these data can be observed. In them, it is contrasted how there are greater differences in the anaerobic threshold according to the speed reached in the tests. On the other hand, if we analyze the HR obtained at the different thresholds, we observe a clear difference between the mountain and diving groups with respect to the UOE and mobility groups.

In the same way, the liters of oxygen per minute (L/min) were also analyzed in the tests (graph 3). In the three thresholds analyzed, significant differences are observed between the groups (p > .05). Also in this case, the mountain and diving groups obtained higher values than the UOE and mobility groups.

If we analyze the comparisons a posteriori (post-hoc), significant differences are observed in terms of HR at the different thresholds compared, being mainly significant between the mountain and diving groups with respect to the UOE and the mobility group (p < .05). At the same time, the same thing happens with the speed reached and the L/min at these thresholds in the different stress tests. However, in these parameters, the same does not occur between mobility groups and UOE, as well as, Mountain and diving (p > .05).

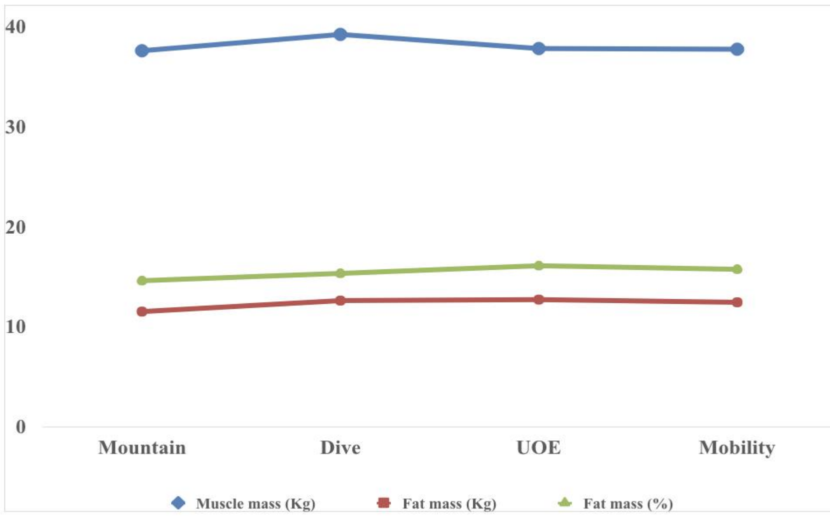

Figure 1. Body composition of the different groups analyzed (p < .05).

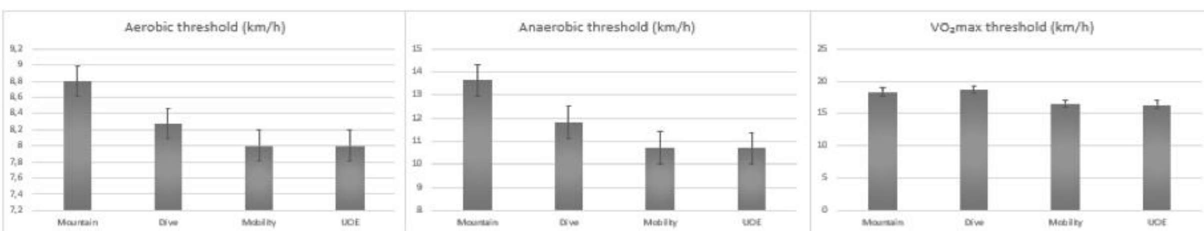

Figure 2. Thresholds established with respect to the speed reached (km/h).

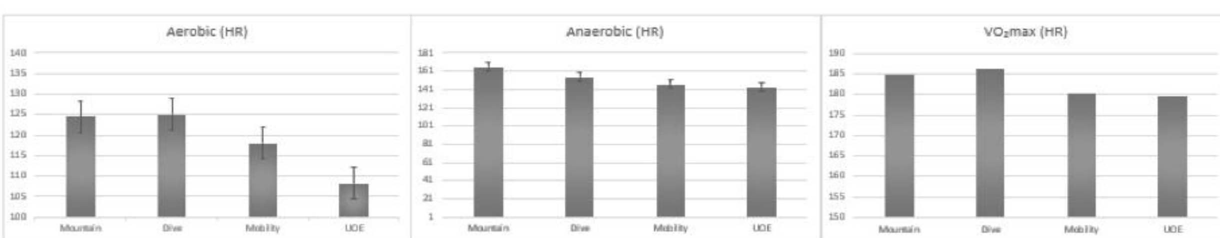

Figure 3. Heart rate reached with respect to the different thresholds analized.

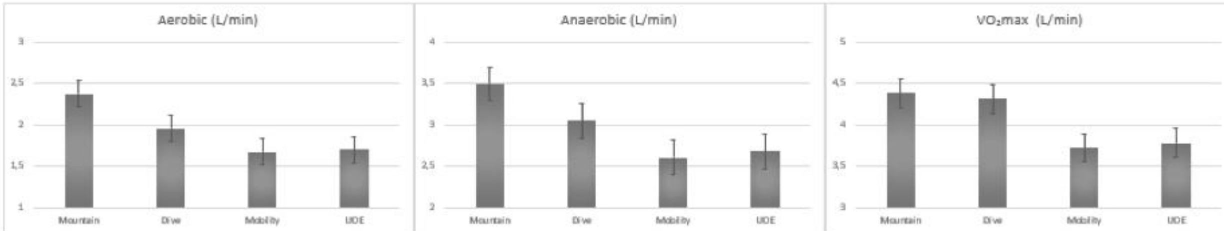

Figure 4. Liters of O_2 (expressed in L/min) reached at different thresholds analyzed.

DISCUSSION

The objective of this study was to establish the differences that exist between the different groups of special operations analyzed according to body composition and physiological parameters measured in stress tests.

Our study observed that there are significant differences in the thresholds reached (VT1, VT2 and VO_2max) with respect to the speed reached in the stress tests ($p < .05$). The same thing happened with respect to the obtained HR, but without significant differences in VO_2max. Differences were also observed between the groups in the liters of oxygen in terms of these analyzed thresholds ($p < .05$).

Despite having been reported in the literature changes in body composition in soldiers through training (Gobbo et al., 2022), and being a widely demonstrated concept, based on these data, no differences in body composition parameters were observed in our study between groups. Although there are differences in the energy demands to which each of the groups are subjected, the body composition is very similar between them. Therefore, despite being groups that carry out totally different activities, their body composition is similar. This characteristic does not occur in other areas such as sports, where there are differences according to the requirements of their respective disciplines (Fields et al., 2018; Bojan Masanovic, 2019; Reale et al., 2020) and even between different levels of the same sport (B. Masanovic et al., 2019; Gardasevic et al., 2019; Bosch et al., 2019).

If we focus on the heart rate and speed reached by the subjects according to the different thresholds analyzed, significant differences are observed between the different groups ($p < .05$). Therefore, in this case there are variations between the different groups analyzed, as occurs in different sports disciplines (Ranković et al., 2010; Souza et al., 2018). The same thing happens with the liters of oxygen assessed during stress tests.

Regarding the specific comparative analysis between the different groups, the mountain and diving groups differ significantly from the mobility and UE group, especially in VO_2max. In this sense, it has been documented in the literature that mountain activities require good physical condition (Burtscher, 2004; Burtscher & Ponchia, 2010; Burtscher, 2012). The importance of good physical fitness, respiratory capacity and body composition are important to achieve good levels of diving and freediving (Lindholm et al., 2007; Rusoke-Dierich, 2018), as well as, an optimal medical and physical examination of your cardiorespiratory capacities to carry out said activity (Weiss, 2003). Therefore, groups specialized in this type of activity must have a good preparation and significant cardiorespiratory fitness. In this sense, our study shows a strong correlation with the existing literature on this topic.

Despite the fact that prediction tests have been used for military performance (Stocker & Leo, 2020) and training oriented according to the specialty they carry out (Sucipta et al., 2018), there is no extensive literature on comparisons between different groups of operations within the military service. Therefore, future research is necessary between different specialized groups in order to guide their training according to the characteristics and demands of the activity and operations they carry out.

Finally, there are certain limitations in our study. On the one hand, the selected groups are not made up of the same number of subjects, which could affect the accuracy of the data. On the other hand, the stress tests carried out have been carried out for months, and the climatic conditions or the type of training of the subjects may vary, as well as their rest and, therefore, changes in the volume of training may have occurred.

CONCLUSION

In conclusion, our study showed that there are no significant differences regarding the body composition of the four groups analyzed, but there are between the speed and HR reached in the different thresholds analyzed. On the other hand, in the L/min observed in these thresholds, significant differences were also demonstrated in the different special operations units of the army.

AUTHOR CONTRIBUTIONS

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

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DISCLOSURE STATEMENT

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SCIENTIFIC JOURNAL OF SPORT AND PERFORMANCE

REVIEW ARTICLE

Hybrid HIIT/isometrics strength training programs: A paradigm shift for physical exercise

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ABSTRACT

Global population statistics demonstrate clear evidence that unhealthy lifestyle choices - including hyper-caloric, low-nutritional density diets and sedentary lifestyle - are raising the global burden of diseases, morbidity and mortality at alarming rates. Healthy diets and exercise are recommended by all health care professionals as a proven treatment and prevention measure for health conditions, yet less than 10% of the population in some countries rigorously follow the minimum physical activity recommendations. In addition, many that do follow physical exercise-and-diet recommended guidelines do not achieve tangible results due to questionable methodologies of such programs. Furthermore, the recent COVID-19 pandemic dramatically affected global healthcare and has contributed to exacerbate the situation due to imposed lockdowns, where the costs of sedentary lifestyles threaten to bankrupt an already overtaxed public health care. Consequently, the public health worldwide desperately needs practical and cost-effective measures to reduce the effects of non-communicable diseases. Muscle mass hypertrophy-based physical exercise and biological adapted diet could provide the physiological solution, while novel game-based technology could help the challenges of exercise compliance. This review aims to, firstly, to revise the importance of achieving, maintaining and recovering muscle mass and strength for improved health outcomes. Secondly, evaluate the benefits of directing the focus of medical interventions towards hypertrophic exercise and diet as an effective treatment to improve health and longevity. Thirdly, we propose the CyFit SmartGym, a novel device, as a potential screening tool for monitoring strength levels and as a HIIT/strength training for improving and documenting health outcomes.
Keywords: Performance analysis of sport, Physical conditioning, Isometric training, Physical exercise, Muscle mass, Strength training.

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INTRODUCTION

Presently, it is well established that poor lifestyle choices, particularly lack of physical exercise, leads to morbidity-inducing conditions and consequent increase in mortality rates (Danaei et al., 2009). In addition, the recent COVID-19 pandemic has contributed to inflame such a situation due to the imposed lockdowns (Kaur et al., 2020; Robinson et al., 2021). That is why establishing more cost-effective interventions to maintain the muscle mass quality and function should be one of the main government challenges. Mobility and physical independence is determined by physical fitness (i.e. on the quality of muscle mass) (Garatachea et al., 2015). The importance of muscle mass and strength in physical performance, as well as in daily activities has never been questioned. However, its vital role in the genesis of many common chronic diseases and conditions including aging is often ignored and generally as many do not appreciate what this actually represents for overall health. Current healthcare systems rarely evaluate muscle mass function or strength (Srikanthan and Karlamangla, 2014).

Notwithstanding, the importance of physical exercise implementation as an additional prescription to combat morbidity-inducing conditions such as hypertension, diabetes and depression is constantly gathering further attention (Micallef, 2014a, 2014b). In addition, early-age inception of a pro-physical health mindset in schools can enhance the development of future generations, having increased awareness on how to attain physical and mental wellbeing through consistent physical activity across adulthood (Micallef et al., 2010).

Unfortunately, despite such awareness, such implementations within individual lifestyles (including exercise-prescribing) fail to be sustained on a long-term basis. such issues exist since, in the general population mindset, the appropriate physical exercise regimes required to achieve well-being, weight loss and/or increase muscle mass and stamina generally revolve around the concept that such regimes are highly time consuming and focus mainly on cardiovascular activities. Most individuals' aversion towards consistent physical exercise can be narrowed to three main issues, namely a perceived lack of time availability to invest in physical exercise, lack of swift and tangible positive outcomes following physical exercise and a consequent lack in motivation to continue physical exercise regimes (Sluijs et al., 1993).

Consequently, the effectiveness of prescribing physical exercise regimes to the individual patient can be considered as possibly futile, unless such a prescription is integrated with methodologies that can constantly register and monitor patient compliance (vis a vis physical exercise), training intensities, documentation and specific bio/markers, together with iterative modifications to ensure maximized effectiveness for the patient through a truly bespoke physical exercise program compliance.

Thanks to modern technology, there is an opportunity to improve self-efficacy within the design of health solutions. Methods that include biofeedback, interactive games, competitions, videos and self-monitoring, similar to that used in commercially available fitness trackers, have the potential to improve the self-efficacy and ultimately the adherence of users (Argent et al., 2018), though the ultimate challenge remains the maintenance of individual motivation to continue such time-consuming physical exercise programs.

There has been a recent trend development in other forms of physical activity programs that are less time-consuming and do provide rapid benefits in those individuals that choose to comply fully to such regimes. Such revolutionary regimes include high intensity interval training (HIIT) and isometrics training programs, can actually lead into a paradigm shift concerning recommended physical exercise strategies that can be consistently sustained throughout an individual's lifetime. Such techniques are becoming ever-more attractive since combined HIIT and isometric training programs only require two weekly training sessions of a maximum of 10 minutes / session, compared to the typical 30 minutes of daily recommended cardiovascular-based physical activity, with such novel and concise exercise regimes providing comparatively swift results within weeks of adoption by the individual (Pérez-Turpin et al., 2019).

In addition, it is important to emphasize that both HIIT and isometric training programs are based upon muscle mass modulation for their effectiveness and can actually provide further benefits compared to currently mass-recommended cardiovascular activity-based exercise regimes (Cuddy et al., 2019; Petrofsky, Batt, et al., 2007, 2006). This is due to the fact that muscle mass plays a pivotal part in the body's metabolism due to it being the main source of amino acids for healthy levels of protein synthesis in essential organs and tissue types (Wolfe, 2006).

In addition, this review article serves to shed more light on muscle-mass-modulation training techniques and also describes routes through which a defined through a combined HIIT and isometrics-based training program, can incept important changes within individual mindsets regarding the minimum effective amount of time investment is required for attaining and maintaining physical well-being.

THE IMPORTANCE OF FUNCTIONAL MUSCLE MASS

Skeletal muscle is the most abundant tissue in non-obese adults, accounting for up to 50% of total body weight in a healthy, athletic individual (Janssen et al., 2000). Skeletal muscle also plays a central role in whole-body metabolism, including the maintenance of protein synthesis (Wolfe, 2006), contribution to proper glucose and lipid metabolism (Jeukendrup et al., 1998) and acting as a major determinant of basal metabolic rate (Konopka et al., 2014; McNab, 2019; Vásquez-Alvarez et al., 2021) – thus rendering contractile muscle as the most active metabolic tissue within higher-order organisms, including humans.

Furthermore, deficient muscle metabolism plays a key role in the aetiology of many common pathologic conditions and chronic diseases (Wolfe, 2006), having a clear relationship between higher levels of muscle mass with improved life expectancy and longevity (McNab, 2019; Vásquez-Alvarez et al., 2021; Wolfe, 2006). The past decade has also been decisive for the identification and in-depth research efforts on the prospects of skeletal muscle acting as an endocrine organ, through the release of myokines that have a myriad of autocrine / paracrine influences, consequently shedding more light on communication / interplays between skeletal muscle and other vital organs (Fiuza-Luces et al., 2013; Pin et al., 2021a). Skeletal muscle mass - through physical exercise-driven myokine release - can also be key mechanistic players for influencing metabolism, anti-inflammatory and adaptive effects (Ahima and Park, 2015; Gonzalez-Gil and Elizondo-Montemayor, 2020; Nimmo et al., 2013; Pin et al., 2021b), as well as resistance to stress and disease (Anker and Coats, 1999; Biolo et al., 2002; Sugden and Fuller, 1991) and cognitive improvement (van Praag, 2009).

Through a physiological perspective, the maintenance of skeletal muscle mass is of obvious and vital importance for sustaining essential and continuous processes such as ventilation, cardiac output and circulatory function, efficient peristalsis within the gastro-intestinal tract and locomotive force for providing mobility, among other pivotal roles. Consequently, the development and strengthening (hypertrophy) of muscle mass, together with atrophy prevention, is of paramount importance for the attainment and maintenance of a healthy body.

THE DANGERS OF LOW MUSCLE MASS

Following from the above descriptions, given its central role in human mobility and metabolic function, any deterioration in the contractile, material and metabolic properties of skeletal muscle has an extremely important effect on human health (Sakuma and Yamaguchi, 2012), playing a key role in the prophylaxis and attenuation of a myriad of common chronic diseases, such as obesity, type 2 diabetes, hypertension, metabolic syndrome, cardiovascular diseases, osteoarticular diseases, chronic kidney and non-alcoholic fatty liver disease and cancer (Harrison and Leinwand, 2008; Jang et al., 2021; Kim et al., 2018, 2021; Lee et al., 2021; Low et al., 2021; Muchai Manyara et al., 2021; Rupert et al., 2021). In all such cases, muscle mass hypertrophy was found to be beneficial for disease prophylaxis and/or disease regulation.

Dramatically and unfortunately, the average muscle mass in adults is decreasing due to unhealthy lifestyle patterns, which combine an inflammatory and high-glycaemic diet pattern (GBD 2017 Diet Collaborators, 2019; Spreadbury, 2012) with a decrease in the level of intensity and volume of daily physical activity (Booth and Roberts, 2008; Owen et al., 2010), causing a deterioration of muscle mass and therefore a detriment to health and productivity. Due to this, annual global cases of a myriad of morbidity and mortality-inducing conditions are on the rise, leading to decreased quality of life and increased functional limitations, ultimately placing additional burdens on social and healthcare budgets.

MUSCLE MASS HYPERTROPHY LEADS TO INCREASED LONGEVITY

There is a clear relationship between the levels of muscle mass and a better life expectancy and longevity (Hettinger et al., 2021; Srikanthan and Karlamangla, 2014; Yerrakalva et al., 2015). Muscle mass is regarded as an excellent indicator of physical well-being as typically, since chronic disease conditions such as cancer and cardiac failure can lead to severe depletion of muscle mass, together with reduction in physical strength and metabolic activity (Wolfe, 2006). This muscle wasting condition is known as cachexia (Wolfe, 2006). Other essential conditions whereby increased muscle mass and contractility properties play pivotal beneficial roles include regulation of sarcopenia, obesity, insulin resistance, diabetes and osteoporosis (Wolfe, 2006; McCormick and Vasilaki, 2018). Consequently, one can infer that the status of muscle mass within an individual and/or patient can extrapolate to the actual health condition within the individual and, in addition, enhance assertions for life expectancy. Unfortunately, recent research revealed that overall youth muscle strength parameters are in decline. The study carried out by Hollmann and Schifferdecker-Hoch focused on a comparative analysis of readouts for grip and lateral pinch potential in millennials (20 – 34 years old) and equivalent mid-1980s youth datasets (Hollmann and Schifferdecker-Hoch, 2017). The results of this investigation highlighted that millennials' mean grip readouts were decreased, with only a mean grip-weight of 20% in men and 14% in women (Hollmann and Schifferdecker-Hoch, 2017).

Despite the above statistics, any individual who makes the solid commitment to improve their general well-being and overall health status through consistent physical exercise programs, can fruitfully benefit from such a lifestyle choice. A recent long-term study (19 years), carried out by Florido and colleagues, focused on monitoring 11,351 patients participating in the Atherosclerosis Risk in Communities (ARIC) study for heart failure events (Florido et al., 2018). This study revealed that all participant groups who complied with the minimum recommended physical activity programs consistently, had a lower incidence of heart failure events (Florido et al., 2018). This trend was also identified within participant cohorts that commenced / intensified their level of physical activity in late middle-age (55+), consequently providing further evidence for the beneficial effects of physical activity in circumventing heart failure event onset (Florido et al., 2018). Furthermore, one of the UK Biobank studies recently carried out on a cohort of 476,559 individual participants (together with an additional 1162 schizophrenia patients) demonstrated that handgrip strength was intimately related to cognitive function, especially regarding processing rapidity and functional memory capacities (Firth et al., 2018). Such a large-scale study finding certainly provides further evidence to validate the importance and utility of increased muscle mass and strength, at any age bracket, in mitigating against physical and mental morbidity-inducing conditions.

MUSCLE MASS QUALITY EXPRESSED THROUGH STRENGTH TESTING

The study conducted by Newman and colleagues in 2006, serves to provide more data revealing the main importance of muscle strength, rather than muscle mass, which is directly related to patient health status and metabolic age (Newman et al., 2006). In brief, this study analysed mortality prevalence among a cohort of 2292 heptagenarian participants. Physical functions such as knee extension strength and grip strength were recorded, together with thigh muscle area and limb soft tissue mass values being recorded (Newman et al., 2006). The study results concluded that reduced muscle mass could not account for the robust interplays between strength and mortality, rendering muscle strength and quality the most essential factor (rather than muscle mass) for calculating mortality risks (Newman et al., 2006). Similar results were recognized by the study performed by Ma and colleagues in 2018 on Chinese osteoporosis patients (Ma et al., 2018). In this particular investigation, over 1100 elderly individuals (> 60 years of age) were treated to a generalized health status check that included calcaneal measurements as a means of identifying possible osteoporosis. In addition, skeletal muscle mass and strength were measured through grip strength and appendicular skeletal muscle mass assessments (Ma et al., 2018). The results of this investigation elucidated that muscle strength is the main parameter that is negatively related to osteoporosis in geriatric patients.

HIGH INTENSITY INTERVAL TRAINING (HIIT)

The practicing of HIIT essentially involves reduced time periods of severely intense cardiovascular activity that typically led to anaerobic conditions within the implicated muscle groups, bridged by rest intervals in order to allow body recovery from any oxygen debts (Laursen and Jenkins, 2002). The main scope of such highly intensive, though short-lasting, physical activity is for increasing overall athletic capacity and also to maximize glucose metabolic processing activities (Laursen and Jenkins, 2002). In addition, HIIT proved to be highly effective, compared to traditional cardiovascular activity, for reducing adiposity in volunteer cohorts (Tremblay et al., 1994). The study carried out by Tremblay and colleagues evaluated, among other factors, loss of adiposity in two volunteer cohorts – one assigned a 20-week endurance training and another cohort assigned a 15-week HIIT training program (Tremblay et al., 1994). The study results demonstrated that overall loss of adipose tissue within the HIIT cohort was nine-fold higher compared to the endurance-training cohort (Tremblay et al., 1994). In essence, HIIT is highly effective on multiple levels - with drastically reduced workout periods – since oxygen consumption is highly increased (leading to a burst in caloric expenditure), inducing a triggering effect on individual metabolic rate to remain elevated for hours post-workout due to excess post-exercise oxygen consumption (EPOC), increased adipose tissue expenditure for restoring homeostatic metabolic rate, increased effectiveness in lactic acid removal and – most importantly – lead to up-regulation of human growth hormone, testosterone and insulin-like growth factor-1 for rapid repair of skeletal muscle proteins and ultimately enhancing muscle mass and strength accordingly ("*7 Reasons HIIT is So Effective*", 2020; Ben-Zeev and Okun, 2021).

It must also be emphasized that, due to the intense demand for protein synthesis placed upon the body during individual HIIT sessions, such a physical exercise program should always be integrated with a bespoke high-protein diet (Layman et al., 2015; Wu, 2016) in order to achieve optimal results during HIIT workout sessions, thus ensuring maximum increases in skeletal muscle mass and strength for the individual participant.

ISOMETRIC STRENGTH TRAINING

The first mentioning of isometric evaluation from muscle excitation studies was the investigation carried out by Dean at the turn of the last century (Dean, 1901). The concept of isometrics training essentially consists of static muscular contraction-based exercise regimes (Mitchell and Wildenthal, 1974). The review by Mitchell and Wildenthal describes dynamic physical exercise as leading to length alterations in the utilized muscles groups, with no change in muscular tension, primarily involving cardiovascular-based activities such as running, cycling or swimming (Mitchell and Wildenthal, 1974). Conversely, isometric physical exercise leads to alterations solely within muscle tension, with minute or no alteration in muscle length, primarily involving resistance-based activities such as lifting / pushing weight-loads or muscular contractions against fixed objects (Mitchell and Wildenthal, 1974). Later studies also highlighted that isometric-based physical activities led to much higher strength development, when compared to equivalent dynamic activity-based physical exercises (Jones and Rutherford, 1987). The study conducted by Jones and Rutherford established that following a 12-week isometrics training program, there were marked increases in isometric forces generated per fixed-cross-sectional area by the involved muscle groups (11-15 %) (Jones and Rutherford, 1987). In addition, this seminal study also highlighted that eccentric (muscle stretch-based) isometric training led to a 45% increase in isometric strength gain when compared to concentric (muscle shortening-based) isometric training programs (Jones and Rutherford, 1987). These observations suggest that the larger increase in forces, seen as a result of isometric training, can be explained by the greater degree and duration of muscle activation, when compared to dynamic training (Jones and Rutherford, 1987).

Interestingly, the series of experiments conducted by Hettinger and Muller led to a number of important findings (Hettinger et al., 2017; Hettinger and Muller, 1953), namely:

a) A training stimulus of approximately 20 % of the maximum force (Fmax) led to muscle atrophy, while a stimulus of approximately 45% Fmax led to a weekly increase in isometric strength by approximately 5%.
b) A training stimulus with a minimum duration of two seconds at maximum isometric contraction (MIC) – or 4 – 6 seconds at 40% MIC level - was sufficient for providing isometric strength gains.
c) Only one daily training stimulus was required for attaining maximum isometric strength increase. Increasing to a daily frequency of up to 7 training stimuli served no additional isometric strength gains.

Apart from rapid and consistent isometric muscle mass strength gains, isometric exercise training programs prove to be of major benefit in mitigating against multiple morbidity-inducing medical conditions.

Interestingly, the study performed by Petrofsky and colleagues in 2006 focused on the effect of concomitant contraction of both agonist and antagonist muscle groups as a form of isometric strength training (Petrofsky, Batt, et al., 2006). The study involved 17 participants that were encouraged to perform both isometric exercise through muscular co-contractions, together with conventional weightlifting-based exercises for three body areas (arm, trunk, leg muscle groups). The study results revealed that isometric co-contraction of muscle groups provided a five-fold increment in training outcomes (weight mass / strength gain) in comparison to conventional muscle training exercise regimes (Petrofsky, Batt, et al., 2006). Following from this study, the Petrofsky group also performed a secondary investigation focusing on the effectiveness of implementing such isometric exercise programs together with a monitored dietary program and was found to be highly successful in achieving both weight loss and muscle gain outcomes (Petrofsky, Batt, et al., 2007).

Previous studies on multiple hypertensive patient cohorts that underwent dynamic or isometric physical training routines revealed that those patient cohorts opted into the isometric training regime experienced a more effective and sustained reduction in systolic and diastolic blood pressure levels accordingly (Fiuza-Luces et al., 2013). Furthermore, a separate, 12-year study conducted by Grontved and colleagues in 2015 focused on the possible correlations for isometric muscles strength and cardiovascular risk factors within 332 youth study-participants, that were monitored until young adulthood (Grøntved et al., 2015). Isometric back extension / abdominal flexion exercises were registered through a strain-gauge dynamometer (typical instrument utilized for measuring isometric exercise force exertions), while cardiorespiratory status was recorded through maximum cycle ergometer analyses (Grøntved et al., 2015). The results of this long-term, large-scale study revealed that augmented isometric muscle strength within youth is intimately related to a reduction in cardiovascular risk factors once such individuals entered young adulthood, with this relationship being independent of individual fitness levels, degree of adipose tissue presence or other interfering issues (Grøntved et al., 2015). In addition, nearly all individuals from this 12-year study (n = 217) were also monitored for the possible interplays between isometric exercise routine adoption and long-term glucose metabolism parameters (Grøntved et al., 2013). Following identical isometric exercise regimes performed in the previously above-described study (Grøntved et al., 2015), insulin resistance and β-cell function assessments were performed through the monitored analyses of fasting serum insulin levels and glucose for the entire 12-year study period (Grøntved et al., 2013). The results for this parallel long-term investigation demonstrated that the consistent adoption of isometric exercise routines in youths, increased isometric muscle strength levels were inversely linked to fasting insulin levels and insulin resistance, suggesting that embracing such physical activity can mitigate against diabetes Type II development in adulthood (Grøntved et al., 2013).

Additional benefits of isometric exercise training routines include amelioration of condition in atrophied muscle groups (Friedebold et al., 1959; Friedebold and Stoboy, 1968) and was also found to provide equivalent / enhanced positive outcomes within individuals practicing isometric exercise routines, in comparison to conventional, cardiovascular-based dynamic exercise regimes (Burgess et al., 2007). Such study results also demonstrated isometric exercise routines to be less stressful on the individual’s body, while also achieving elevated positive outcomes following minimal time investments by the individual (Burgess et al., 2007).

Interestingly, the study carried out by Schnohr and colleagues on approximately 5000 individuals (1098 joggers / 2950 healthy non-joggers), discovered that over-strenuous / over-frequent jogging routines actually proved to be detrimental and contributing to increase in all-cause mortality, thus suggesting that the ideal physical training program should be brief, intensive and infrequent (Schnohr et al., 2015).

HYBRID HIIT/ISOMETRICS STRENGTH TRAINING PROGRAMS: THE CYFIT SMARTGYM SOLUTION

The exercise-induced adaptation of the skeletal muscle during conventional endurance and resistance training has been demonstrated in multiple studies (Miyamoto-Mikami et al., 2018). Furthermore, studies that compare high-intensity aerobic interval (HIIT), resistance training (RT), and combined have shown that all of the training types enhanced insulin sensitivity and lean mass, but only HIIT and combined training improved aerobic capacity and skeletal muscle mitochondrial respiration and reversed transcriptional signature of aging(Robinson et al., 2017).

Following analyses of the considerable advantages and rapid results of both isometric and HIIT training programs the authors have developed the Cyfit Smartgym as a potential tool to increase overall strength levels, physical performance to all users and prevent or attenuate specific morbidity-inducing disease conditions.

The Cyfit Smartgym serves as a prototype isometric and HIIT training program and progress monitoring mobile package. The unit is portable, permits screening, training, documentation and supervision. The software can deliver tangible results with 10 minutes training sessions. Implementation of the Cyfit program, together with a biological adapted diet can lead to concrete positive outcomes, including weight loss. The Cyfit Smartgym can be linked to a cell phone application and measures real-time force production, total force production and additionally provides data on intensity, triangulated goals and progress reports. The complementing software package also employs a game-based technology with competitive elements in order to overcome the participants' three greatest challenges to exercise: lack of time, lack of tangible results and progress and motivational issues. The Cyfit Smartgym is linked to a body-fat scale and smartwatch, allowing it to perform as a comprehensive and independent health system that can be monitored remotely by health and fitness professionals typically coaching the participant. In addition, there is some evidence that wearable devices can improve long-term physical activity and weight loss outcomes (Fawcett et al., 2020).

This novel prototype for introducing hybrid isometric and HIIT training programs to mainstream markets provides proof-of-concept for the employment and regulation of physical activity. Together with associated and relevant datasets, the Cyfit Smartgym can reveal evolutions (or regressions) in physical status, consequently conveying awareness to the health professional to initiate medical interventions when necessary.

Since, as described above, overall strength levels can be utilized as a phenotypic biomarker for assessing generalized health and life expectancy, the Cyfit Smartgym was designed to determine isometric-training-derived strength levels as a means of calculating "*biological age*" of the individual participant, together with a "*life expectancy*", based on such readout datasets, post-training sessions.

Presently, a handgrip dynamometer (non-motorized dynamometry) is employed for measuring isometric exercise session parameters, though this focuses solely on the wrist flexor muscle group (Hurley, 1995; Barbat-Artigas et al., 2012). Consequently, the Cyfit Smartgym caters for such an issue through the development of a novel dynamometer that can register the activity of up to five separate muscle groups within a five-minute exercise session.

A detailed study carried out by the University of Alicante (Pérez-Turpin et al., 2019) render the Cyfit Smartgym to be clinically validated to provide accurate and rapid assessment of individual health status (through determination or isometric strength capacity) and life expectancy.

This study protocol was designed according to a previous similar study conducted by Guerra and colleagues (Guerra et al., 2017) and one of the conclusions stated that the use of the Cyfit-based dynamometer offered increased advantages over conventional handgrip dynamometers since it measures multiple muscle groups, thus leading to a more comprehensive and thorough assessment for isometric strength and consequent general health status determination within the individual.

Thus allowing the health professional to have more complete data and foresight when clinically managing patients.

One further advantage brought by the Cyfit Smartgym training package is that it provides motivational-oriented audio-visual feedback with challenging and competitive games, encouraging the user to train more intensely. Although there presently are many applications that use games to increase physical activity, there has not been any such applications focusing to create measurable high-intensive strength training, designed to improve muscle development. Having real time training intensity goals can improve training results in a way difficult to reproduce. In addition, the utilization of full-screen Smart graphs depicting multiple parameters (both health status-directed and current training session-directed) further enhance motivational mindset within the individual user for self-analysis and self-development for his/her strength training journey.

Figure 1. Training with CYFIT.

CONCLUSIONS AND PERSPECTIVES

In essence, the Cyfit Smartgym represents a novel and functional approach to hybrid HIIT/isometric-based training programs, that are very well proven to provide the much-desired paradigm shift from cardiovascular-based dynamic training programs. Advantages for such a shift include the possibility of users with time-scheduling challenges being able to embrace such reduced training sessions and timeframe session. In addition, isometric exercise regimes have demonstrated to provide additional muscle mass and overall strength gains, adipose tissue loss within the user, in comparison to conventional dynamic training programs. Furthermore, considering the fact that such training sessions are totally gamified leads to more enjoyable experience. It is also important to mention that the Cyfit Smartgym was recently adopted for a study with analogue astronauts for use in Lunar and Marth missions, analysing effectiveness to combat zero-gravity-induced muscle atrophy in astronauts as well as age and or sedentary lifestyle related atrophy on Earth. Future technologies could possibly provide ameliorations to the current manner by which were taught to practice physical education, though at this point in time, hybrid HIIT/isometric training platforms such as the Cyfit Smartgym can provide the answers already, bringing a paradigm shift to our approach and mindset towards physical exercise, with more accurate and reliable ways for monitoring general health and life expectancy to all.

AUTHOR CONTRIBUTIONS

L.W. and G.R.G. manuscript writing. All authors contributed to data organization, management, and analyses along with the writing of the final manuscript.

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