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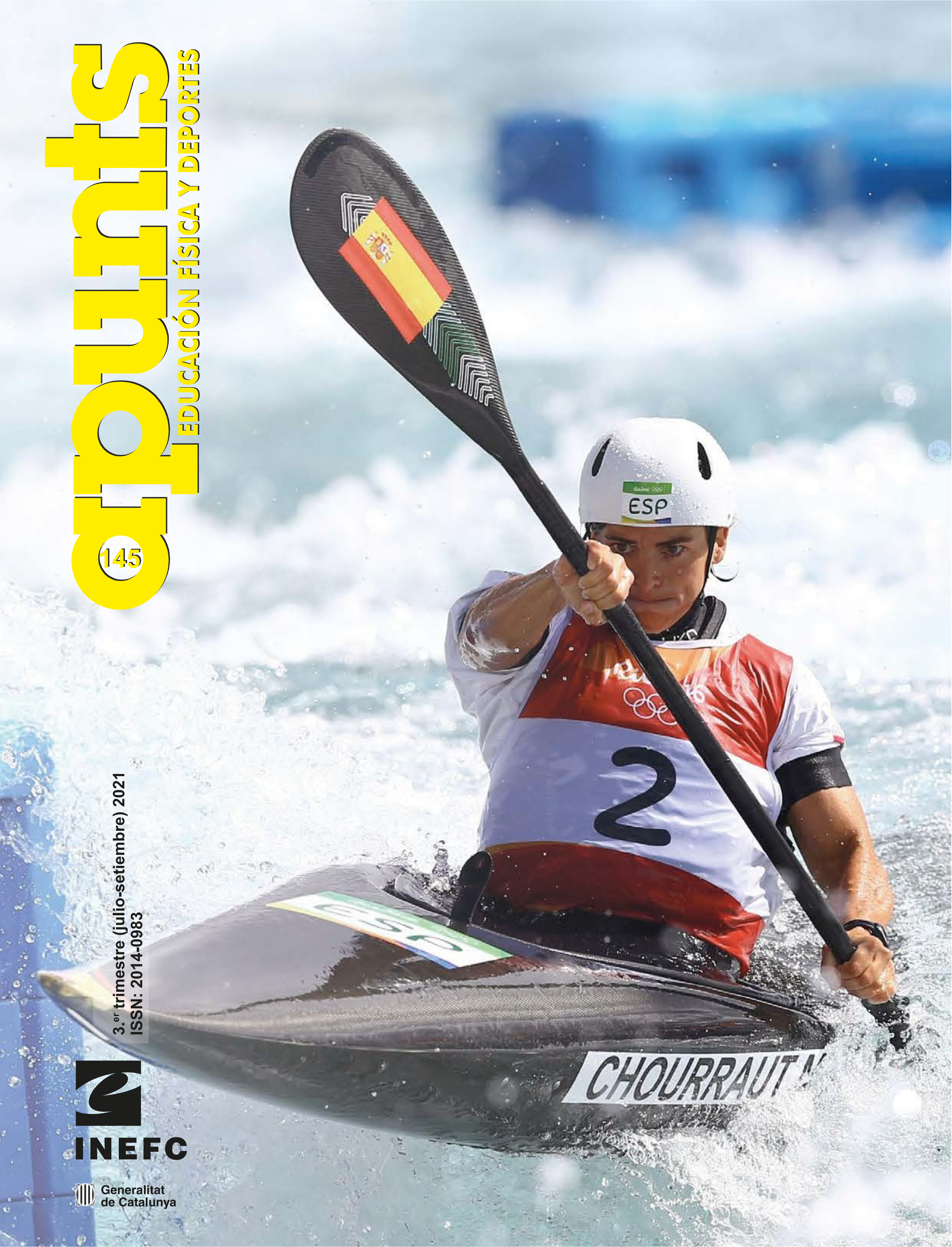

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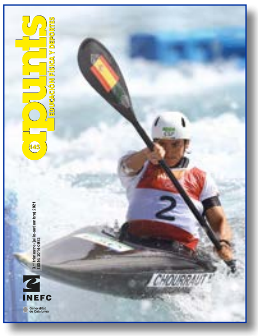

OPEN ACCESS

Evaluation of a Physical Activity Programme in Elderly Non-institutionalised Adults

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Maialen Chourraut (ESP) competing in Rio de Janeiro Olympic Games (2016), Whitewater Stadium. Women's Kayak (K1) Semi-final. REUTERS / Ivan Alvarado

Abstract
Physical activity is one of the key habits that influence healthy ageing, according to WHO. The objective of this study was to evaluate the effect of a physical activity programme conducted in the context of an active ageing workshop on the functional sphere. The study had a single-group pre- and post-intervention design. It included 54 healthy, non-institutionalised adults aged 60 or over. The physical activity programme consisted of 90 twice-weekly group sessions lasting 45-60 minutes over 45 weeks. The participants did stretches and aerobic and muscle-toning exercises rising gradually in intensity throughout the programme. They were assessed with the Tinetti scale, the Timed Up and Go Test (TUG) and the Senior Fitness Test (SFT) at weeks 0 and 45 of the programme. At week 45, we found a significant improvement in mobility according to the TUG and in lower-limb strength evaluated by the SFT. Additionally, we found that gait and balance capacity, determined by the Tinetti scale, remained the same, as did upper-limb strength, aerobic endurance and upper and lower body flexibility, according to the SFT. The study results suggested that the physical activity exercises included in our programme may slow down the loss of functional sphere parameters in adults aged 60 or over.

Keywords: active ageing, elderly adult, functional capacity, healthy ageing, physical exercise.

Introduction

Ageing is a natural phenomenon comprised of "a series of biological, morphological, biochemical and physiological changes that appear as the consequence of the action of time on human beings" (Alvarado-García & Salazar-Maya, 2014).

A person is considered elderly after the age of 65. As of 1 January 2019, 19.3 % of the Spanish population was aged 65 or over (National Statistics Institute, 2020a), and this is forecast to rise to 29.4 % in 2068 (National Statistics Institute, 2020b).

This demographic ageing has a major economic, social and health impact. To reduce the negative social and health repercussions of old age, it is essential to promote active, healthy ageing. Peel et al. (2005) define healthy ageing as "a lifelong process optimizing opportunities for improving and preserving health and physical, social, and mental wellness; independence; quality of life; and enhancing successful life-course transitions".

On the other hand, the World Health Organization's (WHO) (2006) concept of "health" encompasses not only the absence of disorders or diseases but also physical, mental and social wellbeing. Therefore, in the framework of active ageing, health is achieved by policies and programmes aimed at promoting it in three spheres: physical, psychological and social. A healthy elderly person should have the following characteristics: absence of objectifiable diseases, well-conserved functional capacity, autonomy for basic activities of daily living and absence of mental or social problems stemming from their state of health (Sociedad Española de Geriatría y Gerontología, 2007).

WHO (2015) includes physical activity as one of the key habits that influence healthy ageing. Doing regular physical exercise in old age (150 minutes per week at intervals of at least 10 minutes each) helps to preserve cognitive function (World Health Organization, 2010), increase life expectancy and self-esteem, reduce depression and anxiety and the risk of developing different chronic diseases (World Health Organization, 2015).

However, 33 % of people between 70 and 79 and 50 % over 79 do not do the minimum physical activity recommended by WHO (Bauman et al., 2016). This means that it is essential to plan and implement physical activity programmes targeting the elderly.

For this reason, we implemented a physical activity programme in the context of an active ageing workshop for non-institutionalised people aged 60 or above. The objective of this study was to evaluate the effect of this physical activity programme on the participants' functional sphere.

Methodology

A quasi-experimental study was conducted with a single group with two measurements: pre- and post-intervention. The pre-intervention measurements were evaluated before the first session of the physical activity programme commenced and the post-intervention measurements were taken at week 45, after 90 sessions.

Participants

The study population was comprised of non-institutionalised patients seen at the Instituto Valenciano de Neurociencias (IVANN) in the city of Valencia. Non-probabilistic convenience sampling was performed with 54 individuals. The inclusion criteria were: be aged 60 or over, attend more than 75 % of the sessions, not present any problems of complete blindness or deafness, have a favourable report from the medical and psychological team in the preliminary examination and sign the informed consent to participate in the programme. The exclusion criteria were: be under of 60; have orthopaedic, cardiovascular or respiratory problems that would prevent them from following the programme; take medication that might cause gait instability and not agree to participate in the study.

All the participants were informed about the programme, voluntarily agreed to be included in the study and signed the informed consent. The project was approved by the Ethics and Research Committee in Humans of the University of Valencia.

Procedure and instrument

The physical activity programme consisted of 90 group sessions lasting 45-60 minutes held twice a week for 45 weeks. Each session was divided into three phases (Table 1): 1) welcome/warm-up phase, 2) development/main phase and 3) conclusion/cool-down phase.

All the participants in the study were evaluated using the Tinetti scale, the Timed Up and Go Test (TUG) and the Senior Fitness Test (SFT) at weeks 0 and 45 of the physical activity programme.

The Tinetti scale (Tinetti, 1986) is comprised of two subscales, one that evaluates gait (maximum score of 12 points) and another balance (maximum score of 16 points). The overall score determines the risk of falling: scores under 19 indicate a high risk of falling, 19-24 a moderate risk and 25-28 no risk.

The TUG (Abizanda-Soler et al., 2012) measures the time (in seconds) that a person needs to get up from a chair with an armrest, walk in a straight line for 3 metres, turn around, walk back to the chair and sit down. The result has a high inverse correlation with the

Table 1
Phases of the physical activity programme.

Phase	Description	Duration (minutes)
Welcome/warm-up phase	Aerobic activity, rotation of the major joints, stretches and specific warm-up exercises of each session depending on the joints that were to be used the most.	10-15
Development/main phase	Aerobic and muscle toning exercises within games, circuits and joint choreographies gradually rising in intensity throughout the programme.	30-40
Cool-down and stretching phase	Stretches, breathing and muscle-loosening exercises.	5-15

functional mobility level: < 10 seconds = independent mobility, 11-20 seconds = mostly independent mobility, 21-30 seconds = variable mobility, > 30 seconds = reduced mobility.

The SFT battery (Rikli & Jones, 2013) assesses the physical condition of adults over 60. It consists of six tests:

1. Sitting down and getting up from a chair without support: number of repetitions the patient can do in 30 seconds. It assesses the strength of the lower limbs (SLL).
2. Arm Curl: number of arm curls with weights that the person can do in 30 seconds. It reflects the strength in the upper limbs (SUL).
3. 2-Minute Step Test: number of full steps the person can complete in this time. It estimates aerobic endurance (MAE).
4. Trunk flexion seated in a chair with the legs and arms extended forward: distance in cm between the fingers and toes. It determines the flexibility of the lower limbs (FLL), especially the biceps femoris.
5. Back Scratch: distance in cm between the extended fingers of both hands. This shows the flexibility of the upper limbs (FUL), especially the shoulders.
6. Standing, walking and sitting (SWS): the time taken to complete the test in seconds. This indicates agility and dynamic balance.

Data analysis

The quantitative variables were described by means of measures of central tendency: mean, median and mode, and measures of dispersion: standard deviation and ranges. The results were analysed using non-parametric tests, as the variables presented a non-normal distribution. The non-parametric Mann-Whitney-Wilcoxon test was used to verify the homogeneity of the samples. For pre-intervention and post-intervention intrasubject comparisons, the Z statistic was calculated using the non-parametric Wilcoxon signed-rank test. Spearman's correlation coefficient was used for the correlational analysis between the results of different tests. In all cases, a p-value under .05 was established as the level of statistical significance. The SPSS v21 statistical package for Windows was used to process the data.

Results

Sociodemographic characteristics of the population

The study sample consisted of 54 participants aged between 60 and 89 with a mean age of 74. The age range with most individuals was 76 to 80. More women ($n = 35$) than men ($n = 19$) participated. Approximately half the participants had a university education (Table 2).

The main results of the pre- and post-intervention functional tests are shown in Table 3.

Tinetti scale

With regard to the risk of falling measured with the Tinetti scale, no significant differences were found ($p = .941$) between the pre-intervention and post-intervention results in either the aggregate data analysis or in the analysis broken down by sex.

Table 2
Sociodemographic characteristics of the population.

Variables		*n*	(%)
Age range	59-70 years	11	20.37
	71-75 years	17	31.48
	76-80 years	18	33.33
	> 80 years	8	14.82
Sex	Males	19	35.19
	Females	35	64.81
Educational level	Primary	14	25.92
	Secondary	15	27.78
	University	25	46.30

Table 3
Results of the pre- and post-intervention tests.

Test	P25	P50	P75	*Z*	*p*
Tinetti scale				-.073	.941
Pre-intervention	25	28	28		
Post-intervention	25	28	28		
Timed Up and Go Test				-5.023	< .001
Pre-intervention	8	13	18.25		
Post-intervention	8	12	16		
SFT-SLL				-2	.046
Pre-intervention	1.50	2	2		
Post-intervention	2	2			

Timed Up and Go

A statistically significant difference ($p < .001$) was found in the overall results of the TUG after the 90 sessions of the physical activity programme. The percentage of participants with variable mobility fell from 18.5 % ($n = 10$) to 9.3 % ($n = 5$) in favour of the groups with the greatest mobility. The group with mostly independent mobility went from accounting for 46.3% of the participants ($n = 25$) in the pre-test to 50 % of the sample ($n = 27$) in the post-intervention measurement. The participants with independent mobility rose from 33.3 % ($n = 18$) to 38.9 % ($n = 21$).

By mobility groups and sex, no significant changes were found in the men in the groups with reduced mobility ($n = 1$) and variable mobility ($n = 2$). Of the 10 men in the group with mostly independent mobility pre-intervention, 3 obtained post-intervention scores corresponding to the group with independent mobility. Therefore, the number of men with independent mobility increased from 6 (31.6 % of the men) to 9 (47.9 % of the men).

None of the women obtained scores equal to or higher than 30 (reduced mobility). Five women went from having variable mobility according to the TUG to having mostly independent mobility. The group with mostly independent mobility went from comprising 15 women (42.9 % of the women) in the pre-test period to 20 women (57.1%) in the post-intervention period. The 12 women (34.3 % of the women) with pre-test independent mobility maintained this degree of mobility.

Table 4
Cases by sex according to the results of the Senior Fitness Test (percentiles compared to reference value).

Test		Pre-intervention P < 25 *n* (%)	Pre-intervention P25-P75 *n* (%)	Pre-intervention P > 75 *n* (%)	Post-intervention P < 25 *n* (%)	Post-intervention P25-P75 *n* (%)	Post-intervention P > 75 *n* (%)	Difference *p*-value
SLL	F	7 (20%)	25 (71.43%)	3 (8.57%)	7 (20%)	24 (68.57%)	4 (11.43%)	.317
	M	6 (31.58%)	10 (52.63%)	3 (15.79%)	4 (21.05%)	11 (57.9%)	4 (21.05%)	.083
	Total	13 (24.07%)	35 (64.82%)	6 (11.11%)	11 (20.37%)	35 (64.82%)	8 (14.81%)	.045
SUL	F	9 (25.71%)	22 (62.86%)	4 (11.43%)	7 (20.00%)	23 (65.71%)	5 (14.29%)	.180
	M	6 (31.58%)	10 (52.63%)	3 (15.79%)	5 (26.32%)	10 (52.63%)	4 (21.05%)	.157
	Total	15 (27.78%)	32 (59.26%)	7 (12.96%)	12 (22.22%)	33 (61.11%)	9 (16.67%)	.059
MAE	F	12 (34.28%)	19 (54.29%)	4 (11.43%)	12 (34.28%)	19 (54.29%)	4 (11.43%)	1
	M	6 (31.58%)	12 (63.16%)	1 (5.26%)	6 (31.58%)	12 (63.16%)	1 (5.26%)	1
	Total	18 (33.33%)	31 (57.41%)	5 (9.26%)	18 (33.33%)	31 (57.41%)	5 (9.26%)	1
FLL	F	19 (54.29%)	8 (22.86%)	8 (22.86%)	19 (54.29%)	8 (22.86%)	8 (22.86%)	1
	M	12 (63.16%)	5 (26.31%)	2 (10.53%)	12 (63.16%)	5 (26.31%)	2 (10.53%)	1
	Total	31 (57.41%)	13 (24.07%)	10 (18.52%)	31 (57.41%)	13 (24.07%)	10 (18.52%)	1
FUL	F	20 (57.14%)	5 (14.29%)	10 (28.57%)	19 (54.29%)	5 (14.29%)	11 (31.43%)	.317
	M	14 (73.69%)	4 (21.05%)	1 (5.26%)	14 (73.68%)	3 (15.79%)	2 (10.53%)	.317
	Total	34 (62.96%)	9 (16.67%)	11 (20.37%)	33 (61.11%)	8 (14.82%)	13 (24.07%)	.180
SWS	F	14 (40%)	15 (42.86%)	6 (17.14%)	14 (40%)	16 (45.71%)	5 (14.29%)	.317
	M	11 (57.89%)	8 (42.11%)	0 (0%)	11 (57.89%)	7 (36.85%)	1 (5.26%)	.317
	Total	25 (46.30%)	23 (42.59%)	6 (11.11%)	25 (46.30%)	23 (42.59%)	6 (11.11%)	1

Note. F: female (*n* = 35); M: male (*n* = 19).

Senior Fitness Test

The scores in the pre- and post-intervention SLL test presented statistically significant differences ($p = .046$). No significant differences were found in the pre- and post-intervention scores in the other SFT tests. Table 4 shows the number of cases by sex according to the percentiles of their scores in the SFT compared to the reference values (Rikli & Jones, 2013). The men scored better in the SLL and SUL tests, while the women scored better in the other tests. The TUG and SFT results presented a significant correlation in both the pre-intervention period (correlation coefficient -0.579, $p < .001$) and the post-intervention period (correlation coefficient -0.666, $p < .001$).

Discussion

The study sample ($N = 54$) is larger than those of comparable studies (Aman & Thomas, 2009; Solà-Serrabou et al., 2019; Tappen et al., 2000). The sessions were conducted in groups of 12 to 15 individuals led by a psychogerontologist specialising in physical activity and sport, who stimulated the participants' engagement, persistence and performance in the programme. The number of participants included in each group matches the number chosen by other authors (Aman & Thomas, 2009; Tappen et al., 2000). In terms of sample distribution by sex, the predominance of female participants supports the concept of the feminisation of old age due to the higher death rate in men (Aartsen et al., 2004). The age group with the highest participation was 76 to 80, as in the study by Saiz-Llamosas et al. (2014). The lower participation of over-80s compared to other age groups may be due to the lower autonomy and a higher level of institutionalisation inherent in more advanced ages. In terms of educational level, it is noteworthy that almost half of our participants have a university education, compared to the predominance of primary school in the study by Saiz-Llamosas et al. (2014).

The length of the programme (McPhee et al., 2016), the length of each session (Saiz-Llamosas et al., 2014; Solà-Serrabou et al., 2019) and the frequency of the sessions (Solà-Serrabou et al., 2019) match those of similar studies. The time periods chosen are those recommended by Salazar-Pachón et al. (2014), and we believe they are sufficient to achieve the programme objectives and to maintain the participants' attention and motivation without fatiguing them. The tests applied are safe for the participants, socially accepted and easy to score.

The score on the Tinetti scale diminishes every year in healthy elderly people according to a longitudinal study lasting 8 years (Baloh et al., 2003). In our study, all the participants maintained a similar score in this test after 90 sessions of the physical activity programme. Our results indicate that the physical activity programme implemented may contribute to conserving gait and balance capacity in elderly adults.

The scores in the TUG improved significantly overall. By mobility and sex groups, the results in this test did not worsen in any case. This all suggests that physical activity programmes based on exercises involving motor coordination, balance, flexibility, strength and endurance are beneficial in maintaining and/or improving mobility in elderly adults. Our study supports the conclusions of Freiberger et al. (2007) on the effect of these types of exercises on the TUG score after they applied a physical activity programme with weekly one-hour sessions for four months with exercises similar to those of our intervention. The analysis of the 217 elderly participants over the age of 70 from the community found that this type of physical activity produces a significant improvement in scores in the TUG and Sit-to-Stand tests, in addition to reducing the number of falls in the intervention group compared to the control group. The improved mobility measured with the TUG was also demonstrated with other kinds of exercises, such as those based on the Pilates method (Garcia-Garcia et al., 2011) and aquatic exercises (Chou et al., 2012).

With regard to the SFT battery, it is one of the few validated tests for evaluating the physical condition of people over 60 (Rikli & Jones, 2013). In this study, we only found significant differences in one of the six tests, more specifically the evaluation of lower-limb strength, which is essential to maintaining gait. We should note that muscle strength and endurance fall between 15 % and 20 % on average per decade after the age of 50 (American College of Sports Medicine, 2017). Despite this, the scores in the upper-limb strength and muscle endurance tests did not worsen in the 90 sessions of the programme, and good or excellent levels of upper-body strength and optimal levels of aerobic capacity were maintained.

In our study, pre-intervention flexibility evaluated by the SFT fell within the low percentile (P25) compared to the reference values in 73.70 % of the men and 57.10 % of the women for the upper body and in 63.20 % of the men and 54.30 % of the women for the lower body. The percentage of individuals with scores corresponding to the pre-intervention high percentile ranged from 5 % to 20 %, according to sex. This distribution shows that elderly individuals tend to have limited flexibility, as reported in several publications (Latorre-Rojas et al., 2019; Rikli & Jones, 2013). We did not find significant gains in flexibility in either the lower or upper limbs after the intervention. The physical activity interventions designed by other authors obtained mixed results in flexibility, from zero to positive (American College of Sports Medicine, 2017). These discrepancies may be due to the particularities of each type of training and the different limitations presented by studies that evaluate the effect of physical exercise on flexibility in the elderly, such as a small sample size and the absence of control groups.

Finally, we found that the participants evinced an interest in knowing the reference values and how to improve their scores. In other words, the application of the tests within the context of the healthy ageing workshop helped to boost the participants' motivation and engagement in physical activity.

Conclusions

The study results suggest that the physical activity exercises included in our programme may slow down the losses in functional sphere parameters in adults over 60. All the participants were capable of maintaining balance both before and after the intervention. We observed gait and balance maintenance evaluated by the Tinetti scale after the 90 sessions of the programme. Similarly, we found no deterioration in upper-limb strength, aerobic endurance or flexibility of the upper and lower body according to the SFT. Particularly noteworthy is the significant overall improvement in mobility according to the TUG and in lower-limb strength evaluated with the SFT.

One limitation of our study was that there was no control group, preventing us from asserting that the changes are due to the intervention. Similarly, external validity is restricted by the participants' characteristics (belonging to the urban population, autonomous, non-institutionalised). However, this is a common problem in this type of study, as the intrinsic characteristics of physical activity programmes make it difficult to obtain samples that are representative of all population groups.

We continue to hold active ageing workshops with a follow-up programme in which we evaluate the long-term results. We periodically introduce new activities into the workshops to maintain the participants' enthusiasm and motivation. Additionally, we have begun an individual physical activity programme separate from group workshops, with a high degree of acceptance and motivation among the participants. The application of different evaluations of the functional sphere has enabled us to learn more about the participants' individual characteristics to tailor the exercises to their needs.

It is essential to continue implementing and evaluating physical activity programmes for the elderly in order to encourage them to engage in regular, systematic exercise, which is known to be beneficial in maintaining their functionality and independence and therefore in increasing their quality of life.

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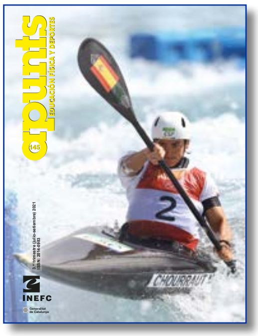

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Comparison of the Efficacy of Three Types of Strength Training: Body, Weight Training Machines and Free Weights

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Maialen Chourraut (ESP)
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Abstract

The objective of this study was to verify which methodology is most effective in improving anthropometric and strength variables: training with free weights, weight training machines or body weight training. 33 male university students did strength training twice a week for eight weeks; they were divided into three training groups: body weight training (ITG), weight training machines (WMTG) and free weights (FWTG). The following variables were evaluated: body mass index (BMI), lean tissue (LT), fat percentage (% fat), sargent jump (SJ), counter-movement jump squats (CMSQ), bench presses (BP), squats (SQ), maximum relative weight in bench presses (MRW BP) and maximum relative weight in squats (MRW SQ). No significant improvements were found in the ITG in the anthropometric and strength variables. In the WMTG, there were significant improvements in % fat and strength levels, while in the FWTG there were significant improvements in % fat, LT and strength levels. Similarly, the FWTG made significant improvements compared to the WMTG in the following tests: JSQ, BP, SQ, MRW BP and MRW SQ. Eight-week strength training applied to university-age males was more effective in increasing strength and lean tissue when performed with free weights than with weight training machines. The use of body weight training did not lead to kinanthropometric or strength improvements. However, it is impossible to totally rule out the possibility that the absence of adaptations is due to the difficulties in quantifying load intensity.

Keywords: free weights, body weight training, strength, weight training machines.

Introduction

Strength training generates multiple benefits, including improved motor performance, sports performance, self-image, health conditions and quality of life, together with the prevention of pathologies and illnesses (Copeland et al., 2019; Ruiz, 2008; Seguin et al., 2013). Given its importance, the scientific community has taken an interest in studying the different factors that condition these improvements. Associations like the National Strength and Conditioning Association, the American College of Sports Medicine, the International Strength Training Association, the American Heart Association and the American Medical Society for Sports Medicine regularly publish reports containing recommendations on the development of this capacity. They also stress its importance both within the context of sport and in health in general. Nonetheless, the strength training planning often lacks scientific approaches and reflects false myths, passing fads or passionate philosophies (López-Miñarro, 2002). Thus, there is some confusion among people doing strength work, who are often unaware of the most effective way to train in order to accomplish their objectives.

In this sense, in recent decades the type of resistance used in strength training has been diversified considerably. The traditional means (bars, dumbbells, elastic bands, weight training machines and medicine balls) have been joined by elements such as vibration machines, unstable surfaces, TRX® bands and kettleballs (Lloyd et al., 2014; Raya-González and Sánchez-Sánchez, 2018). In parallel, the type of physical activity most often used to develop strength has also changed over the years. Until 2013, strength training with body weight training was not among the 20 most common fitness activities worldwide (Thompson, 2014). However, by 2015 it was the most popular, even before HIIT (high intensity interval training), of all training programmes done under the supervision of qualified professionals, conventional strength training and personalised training, which were the second, third, fourth and fifth most popular activities that year, respectively (Thompson, 2017). Different resistances and ranges of motion are used in each of them. However, even although this question sparks a heated debate in the field of physical activity and sport, the one that yields the best results has not yet been thoroughly studied (Schwanbeck, 2018).

Training with body weight training uses one's own body as resistance to work against the force of gravity. Its supporters claim that this methodology allows the exercises to be adapted to each individual's anthropometric features, making greater individualisation possible. They also argue that since the motions are executed within a closed chain, this fosters the participation of different muscle groups in each exercise. Another virtue attributed to body weight training is its effectiveness in improving relative strength, balance and posture control. In contrast, the main disadvantage is the difficulty in quantifying the workload (Harrison, 2010).

Weight training machines offer the following advantages: they are safer for the lifter and allow latter to easily learn different weight training exercises and change the weight load quickly. The disadvantages include the fact that they do not suit the anthropometric features of all subjects and do not allow much neuromuscular activation, given that they stabilise and guide the motions made by the lifter (American College of Sports Medicine, 2009).

Finally, training with free weights allows for a wider variety of motions, and these weights are more functional than weight-training machines in that they can mimic tasks from everyday life as sports gestures. Furthermore, the equipment required is inexpensive. All of this leads to better adherence to strength training. The stimulation of the stabilising musculature is greater when working with free weights than with weight training machines. However, the proper technical execution of exercises using free weights entails a certain degree of difficulty, meaning that they have a longer learning curve (American College of Sports Medicine, 2009).

Finally, bearing in mind that *a priori* the different types of resistance used in strength training have both pros and cons, it is essential to ascertain which one is the most effective. Thus, the goal of this study is to determine which of these three types of training leads to the greatest improvements in strength levels and kinanthropometric parameters: training with body weight training, weight training machines or free weights.

Methodology

Participants

Thirty-three (33) male college students [age: 20.52 (1.45); height: 176.51 (5.23); weight: 74.37 (4.95); BMI: 23.93 (1.37)] were chosen to participate in this study. None of them had experience in strength training or practised organised physical sport activities. Nor did they have any injuries or illnesses which would prevent them from doing the tests and training protocols normally. In an initial pre-study session, the participants were given information on the study's objectives, procedures and characteristics. The benefits and risks of their inclusion in it were also explained to them. They were also asked not to change either their diet or their physical sport habits during the research, to avoid doing intense physical exercise 72 hours before they took the tests, including the pre- and post-intervention, and not to ingest caffeine 24 hours before the tests. This study was conducted observing the ethical principles contained in the Declaration of Helsinki and had the approval of the Institutional Review Board of the Bioethics Committee of Prince Sultan University of Riyadh (Saudi Arabia).

Instruments

The same battery of tests was performed one week before and one week after the intervention period. In both cases, the measurements were:

Kinanthropometric evaluation. Body mass (BM), height and the body mass index (BMI) were measured using a Seca Digital Column Scale (Hamburg, Germany). BM was registered with a precision of 0.1 kg and height with a precision of 0.1 cm. The measurements were taken with the subjects barefoot and by the same researcher. Body fat percentage (% fat) was calculated with the following formula: % fat = [(∑ of abdominal, supraspinal, subscapular, tricipital, quadricipital and peroneal folds)* .143] + 4.56; (González et al., 2006). An FG1056 Harpenden skinfold calliper (Sussex, United Kingdom) was used to measure the fat folds. Lean tissue (LT) was calculated with the following formula: LT = total weight (kg) – fatty mass (kg).

Strength assessment. Before doing the tests, the participants did the following warm-up: a) activation phase, with five minutes of aerobic exercise; b) musculoarticular mobility phase, where they mobilised the main joints from head to toe; c) specific warm-up phase with a series of 10 vertical jumps with and without countermovement plus a series of 10 repetitions without reaching muscle failure in the squat and bench press exercises.

The following capacities were subsequently evaluated:

1. Jump capacity. Two tests were used: jump squat (JSQ) and countermovement jump (CMJ), measured by means of the Optojump device (Bolzano, Italy). In order to prevent the differences in the jump technique among the participants from compromising the validity of the results of both tests, the subjects placed their hands on their hips during the exercise. Both tests were conducted following the protocol of Bosco et al. (1981).

The JSQ started with a 90° knee flexion, with the trunk upright. The jumper then executed a concentric contraction of the knee extensor muscles and kept the trunk vertical during the flight phase. In the CMSQ, they started standing on both feet. The test started with a quick flexion of the knees until a 90º angle was reached. Immediately after that, the subject executed a concentric contraction of the knee extensor muscles, while keeping the trunk vertical. Each participant had two tries in both the JSQ and the CMSQ and only the best result was recorded.

2. Maximum strength. Two tests were performed: squat (SQ) and bench press (BP). The SQ was used to measure maximum lower-body strength. An Olympic bar and Olympic disks were used. Starting by standing on two feet, the subjects placed the Olympic bar on the upper fibres of the trapezius muscle while their feet were at shoulder's width distance apart. They were then asked to flex their knees until their thighs were parallel to the floor. They then had to return to their initial position. Similarly, the BP was used to measure maximum upper-body strength. To do this test, the subjects lay prone on a Hammer Strength bench-press bench with their head and hips in the neutral position. They were then instructed to grasp the bar with their hands at shoulders' width distance apart. Starting from this position, with their elbows extended, they had to lower the bar until it made contact with their chest and then raise it back to its initial position (National Strength and Conditioning Association, 2017). In both the squat and the bench press, the better result of two tries was recorded. Given that the subjects lacked strength training experience, the 1RM was calculated using the Lander formula (Felipe et al., 2013). Both tests were done with 80 % of each subject's estimated 1RM and only the number of repetitions executed correctly was recorded.

3. Relative maximum strength. Once each subject's 1RM in the squat and bench press had been estimated, the relative weight in the bench press (MRW BP) and the squat (MRW SQ) were calculated. For this purpose, the Wilks coefficient was used with the following formula: coefficient $= 500/ a + bx + cx^2 + dx^3 + ex^4 + fx^5$; with (for men): x = the subject's BM in kg; $a = -216.0475144$; $b = 16.2606339$; $c = -.002388645$; $d = -.00113732$; $e = 7.01863E\text{-}06$; $f = -1.291E\text{-}08$. This formula is a valid method for comparing the subjects' relative strength with different weights given that the body mass multipliers favour people with light weights and do not consider allometric relations (García-Manso et al., 2010).

Procedure

Once they had completed the pre-test, the 33 subjects included in the study were divided into three experimental groups: body weight training training group (ITG), weight training machine training group (WMTG) and free weights training group (FWTG). In order to give the study greater internal consistency, make the groups more homogeneous and lower intergroup variance, the following procedure was used to assign the subjects to each of the three experimental groups: according to their scores in the 1RM test in the squat, the participants were divided into 11 clusters, each one comprised of three subjects. The three subjects with the top scores were assigned to cluster one, the subjects with the fourth, fifth and six scores to cluster two and so on. After that, to avoid the influence of possible extraneous variables not assigned to clusters, each of the three members of the 11 groups was assigned randomly to one of the three different experimental groups.

The intervention lasted eight weeks. The programme observed the principles of sports training and the recommendations of the American College of Sports Medicine for strength training with beginners. In summary, three series of each exercise were done, from 6 to 12 repetitions per series, and the rest time lasted between one and two minutes. In the training session, the exercises meant to strengthen the larger muscle groups were performed before those intended for the smaller muscle groups, and multi-joint exercises were performed before single-joint exercises. Eccentric and concentric contractions were included (American College of Sports Medicine, 2009).

The training parameters applied to the three groups were identical (Table 1); however, the exercises were different in each of the groups (Table 2).

To estimate the intensity of the training in the WMTG and in the FWTG, during the week of the pre-test, 1RM was calculated for the exercises used by both groups with the Lander test. Subsequently, during the intervention, the OMNI-RES strength training scale was used (Robertson et al., 2013) to even out the intensity of the training in all three groups. Similarly, in all the training sessions, special attention was paid to ensure that the kind of effort used while doing each exercise (as with the other training parameters) was identical for all three groups.

Table 1
Features of the training applied to the three experimental groups.

	Weeks 1 and 2	Weeks 3 and 4	Weeks 5 and 6	Weeks 7 and 8
Intensity	62 %	62 % - 67 % - 72 %	72 %	76 %
Series	3	3	3	3
Repetitions	12	12 - 10 - 8	8	6
Rest	1’	1’ 30”	2	2
Type of effort	Highest number of repetitions possible per set			

Table 2
Strength exercises used by each of the three experimental groups.

	ITG	WMTG	FWTG
Trunk flexors	Abdominal crunch	Abdominal crunch on machine	Weighted crunches
Trunk extensors	Pelvis lifts	Machine back extension	Roman chair weighted back extension
Leg	Step up and Bulgarian split squat	Leg presses	Lunges with Olympic bar
Pectoral	Push-ups	Chest press	Dumbbell press
Back	Pull-ups (horizontal, oblique and vertical position) wide back grip	Rowing machine	One arm dumbbell row
Elbow extensors	Bench dips (hands separated at shoulder’s width)	Triceps on triceps dip machine	Triceps kickback
Elbow flexors	Pull-ups (horizontal, oblique and vertical position) palm grip at shoulder’s width	Biceps curl on Scott machine	Alternative dumbbell curl

Note. ITG: body weight training group; WMTG: weight training machine training group; FWTG: free weights training group.

Statistical analysis

The results were analysed using the IBM SPSS V.22® computer program. The data were presented using the mean arithmetic format (standard deviation). The Shapiro-Wilk test was used to check the normality of the distribution and the Levene test to verify the homogeneity of the variances. To assess the effect of the training, a two-factor repeated measures ANOVA (RM ANOVA) was conducted. When significant *p* values were found, a *post hoc* analysis was conducted with Bonferroni correction to identify the differences. The intra-subject effect size was calculated with Cohen's *d*, considering $d = .2$ small, $d = .5$ medium and $d = .8$ large. The inter-subject effect size was estimated using the eta-squared parameter (η2), with η2 values = .1, .25, and .40 considered small, medium and large effect sizes, respectively (Cohen, 1988). The level of significance established was $p = .05$.

Results

No differences were observed among the groups in any of the dependent variables evaluated before the start of the training. The RM ANOVA indicated the absence of a time*group interaction and of a principal effect of time in the BM and BMI. In contrast, the existence of a principal effect of time was verified in the LT ($p = .01$; η2 = .247) and in % fat ($p = .002$; η2 = .650). Similarly, a time*group interaction was found for the following variables: JSQ ($p = .02$; η2 = .325), CMSQ ($p = .007$; η2 = .389), BP ($p = .001$; η2 = .594), SQ ($p = .001$; η2 = .58), MRW BP ($p = .000$; η2 = .564) and MRW SQ ($p = .000$; η2 = .547).

With regard to inter-subject differences, the *post hoc* analysis showed that the improvements obtained by the FWTG after the intervention process were significantly higher than those obtained by the ITG in all the strength tests (JSQ: $p = .023$; CMSQ: $p = .003$; BP: $p = .002$; SQ: $p = .035$; MRW BP: $p = .007$; MRW SQ: $p = .036$). The FWTG also showed significantly higher improvements than those of the WMTG in all the strength tests, except the CMSQ (JSQ: $p = .014$; BP: $p < .045$; SQ: $p = .004$; MRW BP: $p < .041$; MRW SQ: $p < .018$). In contrast, there were no significant differences between the improvements attained by the WMTG and the ITG.

With regard to intra-subject comparisons (Table 3), the ITG showed no significant improvements in any of the variables analysed. The WMTG showed significant improvements in all the strength parameters and % fat. Finally, the FWTG showed significant improvements in all the strength measures, % fat and LT.

Discussion

This study has shown that eight weeks of training with body weight training did not lead to kinanthropometric improvements. The WMTG managed to lower % fat, while the FWTG not only lowered % fat but also increased lean tissue. From these results, we can glean that training with free weights is the most effective of the techniques to achieve changes in body composition. However, given that the effect sizes in both the WMTG and the FWTG were small, it is also possible to posit that attaining substantial improvements in body composition requires the application of strength training for considerably longer than eight weeks.

Table 3
Changes recorded in the kinanthropometric variables and strength levels after the application of the three training protocols.

	Group	Pre-test	Post-test	Cohen's *d*	*P*
BM	ITG	74.5 (4.64)	74.3 (4.63)	0.04	.14
	WMTG	74.4 (5.83)	74.5 (5.81)	0.01	.36
	FWTG	74.2 (4.77)	74.5 (4.93)	0.06	.11
BMI	ITG	23.98 (1.22)	23.95 (0.98)	0.02	.90
	WMTG	23.88 (1.60)	23.78 (1.61)	0.06	.47
	FWTG	23.94 (1.39)	24.03 (1.40)	0.06	.12

Note. BM: body mass; BMI: body mass index; LT: lean tissue; % fat: fat percentage; JSQ: jump squats; CMSQ: counter-movement jump squats; BP: bench presses; SQ: squats; MRW BP: relative maximum strength in bench presses; MRW SQ: relative maximum strength in squats; ITG: body weight training training group; WMTG: weight training machines training group; FWTG: free weights training group; *: significant improvement between the pre-test and post-test; +: significant improvement between the FWTG and the ITG; #: significant improvement between the FWTG and the WMTG.

Table 3 (Continuation)
Changes recorded in the kinanthropometric variables and strength levels after the application of the three training protocols.

	Group	Pre-test	Post-test	Cohen's *d*	*P*
LT	ITG	62.16 (3.42)	62.11 (3.41)	0.01	.52
	WMTG	61.97 (4.23)	62.08 (4.23)	0.02	.62
	FWTG	61.87 (3.35)	62.31 (3.54)	0.12	.02*
% fat	ITG	16.54 (1.25)	16.39 (1.25)	0.11	.101
	WMTG	16.60 (1.59)	16.38 (1.50)	0.14	.0001*
	FWTG	16.57 (1.41)	16.30 (1.55)	0.18	.0063*
JSQ	ITG	31.90 (2.12)	32.46 (1.91)	0.27	.10
	WMTG	31.7 (2.17)	32.6 (2.20)	0.41	.0001*
	FWTG	31.60 (1.90)	33.12 (1.65)	0.85	.0001*+#
CMSQ	ITG	35.05 (1.91)	35.63 (1.79)	0.31	.14
	WMTG	34.96 (2.31)	36.58 (2.41)	0.68	.0001*
	FWTG	34.61 (1.88)	37.25 (1.30)	1.63	.0003*+
BP	ITG	53.40 (6.07)	54.90 (4.02)	0.28	.25
	WMTG	53.1 (6.31)	55.9 (6.67)	0.43	.001*
	FWTG	53.30 (4.08)	60.90 (4.83)	1.69	.000*+#
SQ	ITG	82.32 (6.5)	84.57 (7.5)	0.32	.19
	WMTG	82.27 (5.70)	85.87 (5.39)	0.64	.0001*
	FWTG	81.88 (5.50)	91.43 (6.67)	1.56	.0001*+#
MRW BP	ITG	38.63 (5.78)	39.46 (4.28)	0.16	.41
	WMTG	38.18 (4.88)	40.19 (4.97)	0.41	.002*
	FWTG	38.31 (1.94)	43.72 (2.02)	2.73	.0001*+#
MRW SQ	ITG	59.25 (6.39)	60.91 (6.20)	0.26	.18
	WMTG	59.30 (5.17)	61.89 (4.95)	0.51	.0001*
	FWTG	58.89 (2.61)	65.58 (3.03)	2.36	.0001*+#

Note. BM: body mass; BMI: body mass index; LT: lean tissue; % fat: fat percentage; JSQ: jump squats; CMSQ: counter-movement jump squats; BP: bench presses; SQ: squats; MRW BP: relative maximum strength in bench presses; MRW SQ: relative maximum strength in squats; ITG: body weight training training group; WMTG: weight training machines training group; FWTG: free weights training group; *: significant improvement between the pre-test and post-test; +: significant improvement between the FWTG and the ITG; #: significant improvement between the FWTG and the WMTG.

Nor did the ITG achieve significant improvements in strength levels. This finding concurs with the study conducted by Martínez and Cuadrado (2003) with handball players. These authors demonstrated that traditional strength training and combined training (strength exercises chained with explosive movements) are effective in improving maximum strength and explosive strength, while training with body weight training did not generate significant improvements in those two manifestations of strength. However, the reason why training with body weight training is not effective in improving strength and kinanthropometric variables is not entirely clear. One of the reasons may be that there is less muscle stimulation with this methodology, even when the kind of effort is identical to load-bearing exercises. Another possible cause is the lower functionality of the exercises compared to those performed with free weights due to the fact that when body weight training is used, angles and working positions have to be modified to graduate the intensity of the exercises, meaning that less natural positions are sometimes used. Nonetheless, we cannot totally rule out the possibility that the absence of adaptations is due to the difficulties in quantifying the intensity of the training performed with body weight training.

In contrast, the WMTG and FWTG improved results in all the strength tests conducted. Furthermore, the training with free weights was more effective at increasing maximum strength, explosive strength and relative maximum strength than the weight training machines. These results differ from those of Schwanbeck (2018) in a study also conducted with university-age students which found that both weight training machines and exercises done with free weights generate similar increases in LT and strength. In a similar vein, after systematic reviews of different studies on strength, the American College of Sports Medicine (2009) and Fisher et al. (2011) concluded that both methodologies generate similar improvements in strength.

However, other studies results concur with those of this study. Wirth et al. (2016) compared the efficacy of strength training of the lower body using squats and leg presses. The group that trained with squats achieved better results in the JSQ and the CMSQ. The authors attribute this to the higher functionality of squats and their greater similarity to the jump test compared to the leg press. In a similar study comparing the same two exercises, Shaner et al. (2014) verified that squats generate an acute response in growth hormone, testosterone and cortisol, in addition to a higher heart rate and higher lactate concentration. Another earlier study (Shaner, 2012) also found that the acute release of testosterone and of growth hormone is higher after doing squats than after doing leg presses. However, in addition to hormonal factors, another reason why training with free weights may be more effective than weight training machines is that the stabilisation requirements are higher in exercises with free weights, and this requires greater muscle activation (García and Requena, 2011). Fletcher and Bagley (2014) and Schick et al. (2010) also point out that the advantage of doing squats with a bar compared to a Smith machine is that the stabilisation requirements take place on the three planes of motion. Thus, the coordinative difficulty of the exercise is higher, given that the exerciser has to control both load and movement, while also synchronising the actions performed by a greater number of fixator, synergistic and antagonistic muscles. These authors also stress the higher functionality of the squat and believe that the transfer of the strength gains from the squat to other motor situations is more feasible than working with machines that stabilise movement. Here, we should recall that in order to avoid the learning effect, the strength exercise used by the FWTG during the intervention to develop lower-body strength (lunges with bar) in this study was different to what was used with the three experimental groups in the pre-test and post-test to evaluate their lower strength (squats). Nonetheless, the improvements in strength obtained by the FWTG are significantly higher than those in the other two groups; therefore, we can interpret that lunges are also more functional than leg presses.

In consequence, based on the results of this study and bearing in mind those of previous studies, we would assert that when the objective of training is to increase maximum strength or explosive strength, it is better to use exercises with free weights. Weight training machines can also be used, as they also yield improvements in strength levels. But it should be remembered that several studies concur that these improvements may be lower than those achieved with free weights. With regard to body weight training, current scientific evidence tells us that it does not allow for significant improvements in body composition or strength levels. Consequently, it should be used only if there is no possibility of training using free weights or weight training machines. Nonetheless, further studies are needed to confirm that training with free weights yields better results than weight training machines and that the latter are more effective than body weight training.

To conclude, we should mention that the main limitation of this study was the small sample size. A larger number of participants would have afforded this research greater statistical power.

Conclusion

An eight-week strength training applied to university-age males was more effective in increasing strength and lean tissue when done with free weights than with weight training machines. The use of body weight training did not generate kinanthropometric or strength improvements. However, in this latter case we cannot totally rule out the possibility that the absence of adaptations is due to the difficulties in quantifying load intensity.

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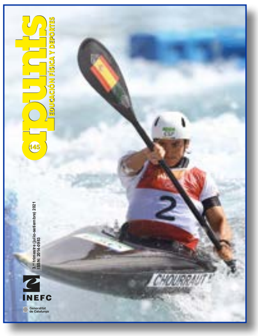

OPEN ACCESS

Effects of Active Versus Passive Recovery in the Bench Press

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Maialen Chourraut (ESP) competing in Rio de Janeiro Olympic Games (2016), Whitewater Stadium. Women's Kayak (K1) Semi-final. REUTERS / Ivan Alvarado

Abstract

The recovery between sets in strength exercises is one of the variables on which physical performance depends, and yet it has scarcely been investigated. Most of the studies on this topic have focused on different recovery intervals, namely the duration variable; however, our objective is to analyse whether active recovery could minimise the loss of power compared to traditional passive recovery, keeping duration constant between both protocols. To achieve this, 14 trained young volunteers did two sets of bench press of eight repetitions each and a third set until muscle failure with an optimal load to develop maximum power. Each set was separated by two minutes of passive recovery without activity or by active recovery with 60 seconds of vertical chest presses at slow speed with low load. The intraset loss of power was lower with active recovery than with the passive recovery, and this difference was statistically significant in the first and third sets (13.34 % vs. 18.84 %, $p = .006$; and 13.38 % vs. 17.53 %, $p = .001$, respectively). We also found a discreet yet significantly higher perceived exertion in the second set (4.5 vs. 5.0, $p = .033$). In conclusion, active recovery may be an appropriate stimulus to minimise intrasession loss of performance and improve perceived exertion in strength exercises.

Keywords: performance, power, recovery, strength.

Introduction

Among the variables we can control when designing strength training programmes, recovery between sets has barely been studied in the scholarly literature (Hernández-Davó et al., 2016). We know that doing more than one set during strength training may be more effective for achieving the desired goals by boosting the volume of training (Schoenfeld, 2016), hence recovery between sets is a key parameter to be borne in mind when prescribing any exercise programme and warrants greater attention for the purpose of determining optimal prescription (de Salles et al., 2009).

Although it is true that some studies have analysed different types of recovery between sets in strength training, they have focused primarily on evaluating how different time intervals influence physiological and/or performance parameters in order to determine the optimal recovery between sets depending on the objectives (Abdessemed et al., 1999; Henselmans and Schoenfeld, 2014; Hernández-Davó et al., 2017; Hernández-Davó et al., 2016; Martorelli et al., 2015; Senna et al., 2016; Willardson, 2006). These studies have focused on the variable length of the recovery period between sets. Moreover, there is considerable heterogeneity in these studies, not only in the samples (men and women, age difference, different physical fitness levels, etc.), but also in the parameters evaluated (maximum number of repetitions the person is capable of completing, percentage of loss of speed, output power, blood lactate concentration, etc.). In this regard, we believe that in the context of physical performance, investigating different types of recovery between sets in strength training should focus on evaluating its effects on the participants' output power.

The maximum power output depends primarily on the metabolic pathways that occur in the skeletal muscle cell cytoplasm, classically known as anaerobic, particularly the phosphagen system (ATP and phosphocreatine, PCr) (Mougios, 2020). Therefore, recovery between sets should allow for a complete or almost complete resynthesis of this system in order to deliver the maximum possible performance during subsequent sets. After a brief, intense effort, such as a strength training set, 50% of initial PCr levels can be restored in the first 30 seconds of recovery and up to 90% can be resynthesised within two minutes (Chicharro and Fernández-Vaquero, 2018). PCr is synthesised thanks to the aerobic metabolic pathways, so oxygen is needed to restore the phosphagen system used during the effort. Therefore, by using active recovery between sets in strength exercises, we can facilitate the irrigation of the musculoskeletal tissue in order to improve oxygen input into the muscle cells, which may in turn help to restore the phosphagen system. This could improve performance in subsequent strength training sets (Gill et al., 2006; Latella et al., 2019).

Several authors have investigated how the length of recovery intervals affects the power output in subsequent sets during strength exercises (Hernández-Davó et al., 2016). It is suggested that for training muscle power, the rest intervals should be between 2 and 5 minutes depending on the type of exercise or the effort made (Willardson, 2006). The decision should be taken with the objective of achieving maximum if not complete resynthesis of the phosphagen system as quickly as possible. Otherwise, in subsequent sets, cytosolic glycolysis would be the predominant metabolic pathway that would satisfy the energy demand involved in the effort, with the consequent accumulation of metabolites (mainly lactate and H+ ions), which could lead to the premature appearance of muscle fatigue, in addition to a slower energy input than with the phosphagen system, taking the energy power or metabolic rate of both systems into account (amount of energy synthesised per time unit) (Mougios, 2020).

For this reason, the objective of this study was to compare the effects of active versus passive recovery on the loss of power and perceived exertion in successive sets during a strength exercise.

Methodology

Our study was a randomised crossover trial in which the participants did both types of interventions proposed: active recovery and passive recovery. Each participant visited our laboratory three times. On the first visit, they performed a maximum power test (Pmax) in the bench press, followed by a test of one maximum repetition (1MR) in the vertical chest press. The objectives of the study and the procedure were explained to them and each participant's demographic data were recorded.

All participants signed an informed consent form and the data were processed in accordance with the laws in force as stipulated in Organic Law 15/1999 on personal data protection and in Royal Decree 1720/2007, as well as the principles enshrined in the Declaration of Helsinki (Association, 2013). This study received a favourable evaluation from the Research Ethics Committee of the Universidad Francisco de Vitoria (42/2018), where it was conducted.

Participants

Fourteen male students participated in this study. The sample size was calculated using the G*Power 3.1.9.2 software with the group of *t*-tests and the difference between two dependent means for paired samples according to the statistical tests for related samples (Faul et al., 2007), considering a one-tailed hypothesis test, an α probability of error of .05, a power (1-β probability of error) of .80 and an effect size of .80 (Cohen, 1992). Thus, the resulting total size was 12 participants to achieve a power of .828, so we recruited 14 volunteers, considering a possible 15% loss during the study.

The inclusion criteria were: males aged between 18 and 24 with at least one year of experience in strength training who regularly engaged in strength training (at least two days a week), were capable of lifting at least 80% of their body weight in the bench press and had no contraindication for doing physical exercise. The exclusion criteria were failure to meet any of the inclusion criteria or not being available to come to our laboratory on the scheduled days.

All the participants were encouraged to keep up their daily habits in terms of physical training and hydration and dietary patterns and were asked to refrain from training their upper body at least 48 hours before the measurement days and from consuming caffeine or any other stimulant or ergogenic aid at least three hours before the measurements were taken.

Procedures

The participants were recruited at the Universidad Francisco de Vitoria, primarily among the students in the bachelor's degrees in Physiotherapy and Physical Activity and Sport Sciences. Potential candidates were asked to fill out on an online form with questions about their age, strength training experience, current exercise habits and possible contraindication for physical exercise. Based on the responses, the results were filtered to recruit the participants that met the inclusion criteria.

All the participants visited our laboratory three times. On the first visit, they did a guided Pmax test in the bench press, following the protocol described by other authors (Bevan et al., 2010; da Silva et al., 2015), and a 1MR test in the vertical chess press. The session started with a general warm-up comprised of five minutes of moderate-intensity cardiovascular activity and general mobility of the joints involved in the bench press exercise, followed by 3-5 minutes of passive recovery. This was followed by a specific warm-up consisting of a set of 10 repetitions of the guided bench press on a rack (Evolution Deluxe Smith Machine and Rack; Titanium Strength, S.L., Spain) without an additional load (the bar weighs 21 kg) at a controlled execution speed (two seconds in the concentric phase and two seconds in the eccentric phase) followed by 4-5 minutes of passive recovery. They subsequently performed a set of three repetitions with 20% of the 1MR estimated by the participant at the maximum execution speed possible, followed by 4-5 minutes of passive recovery.

After this warm-up, the Pmax test was executed via sets of three repetitions at the maximum speed possible with 30%, 40%, 50% and 60% of the estimated 1MR, with a passive recovery of 4-5 minutes between sets. At the end of this test, the 1MR test in the vertical chest press was performed to ascertain the load that would be used in the active recovery protocol. This 1MR test in the vertical chest press involved executing a set until muscle failure with the load equivalent to the 1MR estimated by the participant for that exercise, completing a total of 3-5 maximum repetitions and calculating the 1MR following Brzycki's formula (Brzycki, 1993).

Approximately 7 and 14 days after the first visit to the laboratory, the volunteers participated in the two interventions to compare the differences between active and passive recovery. In a random order, the participants did one of two of the following protocols after the same general and specific warm-up that they had done on the first day. In the passive recovery protocol (PAS), two sets of eight repetitions were performed at the maximum execution speed possible with the optimal load calculated for the Pmax (OptLoad Pmax) and a third set until muscle failure, with a two-minute passive recovery between the sets (Figure 1). In the active recovery protocol (ACT), the participants performed two sets of eight repetitions at the maximum execution speed possible with the OptLoad Pmax and a third set until muscle failure, with the sets separated by a two-minute active recovery of vertical chest presses with 5%-10% of the 1MR at an execution speed of two seconds in the concentric phase and two seconds in the eccentric phase, controlled by a metronome (Metronome Beats 5.0.1) (Figure 2).

Kinetic variables

The mean propulsive power (MPP) of each repetition was recorded with a linear encoder (Chronojump) at a sampling frequency of 1000Hz and software to analyse the data (Chronojump 1.8.1-95) validated by Buscà and Font (2011). The loss of the mean propulsive power (%Loss) was calculated as the difference between the MPP on the first and eighth repetition in each set, according to the calculations published by Sánchez-Medina and González-Badillo (2011) for evaluating loss of speed in strength training. The maximum number of repetitions in the third set (nMR) was recorded as the total number of repetitions performed by the participant until muscle failure.

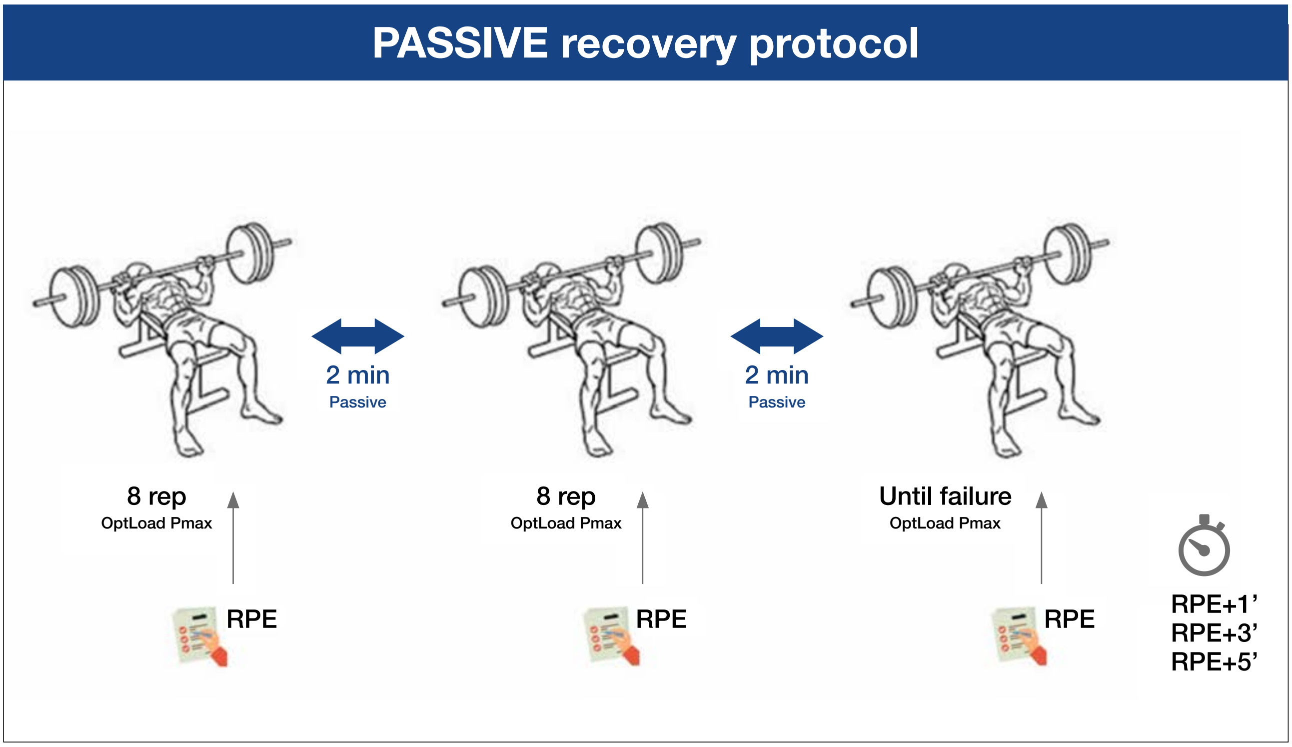

Figure 1
Measurement protocol with passive recovery.
Source: Authors. Note. OptLoad Pmax: optimal load to develop maximum power; RPE: rate of perceived exertion.

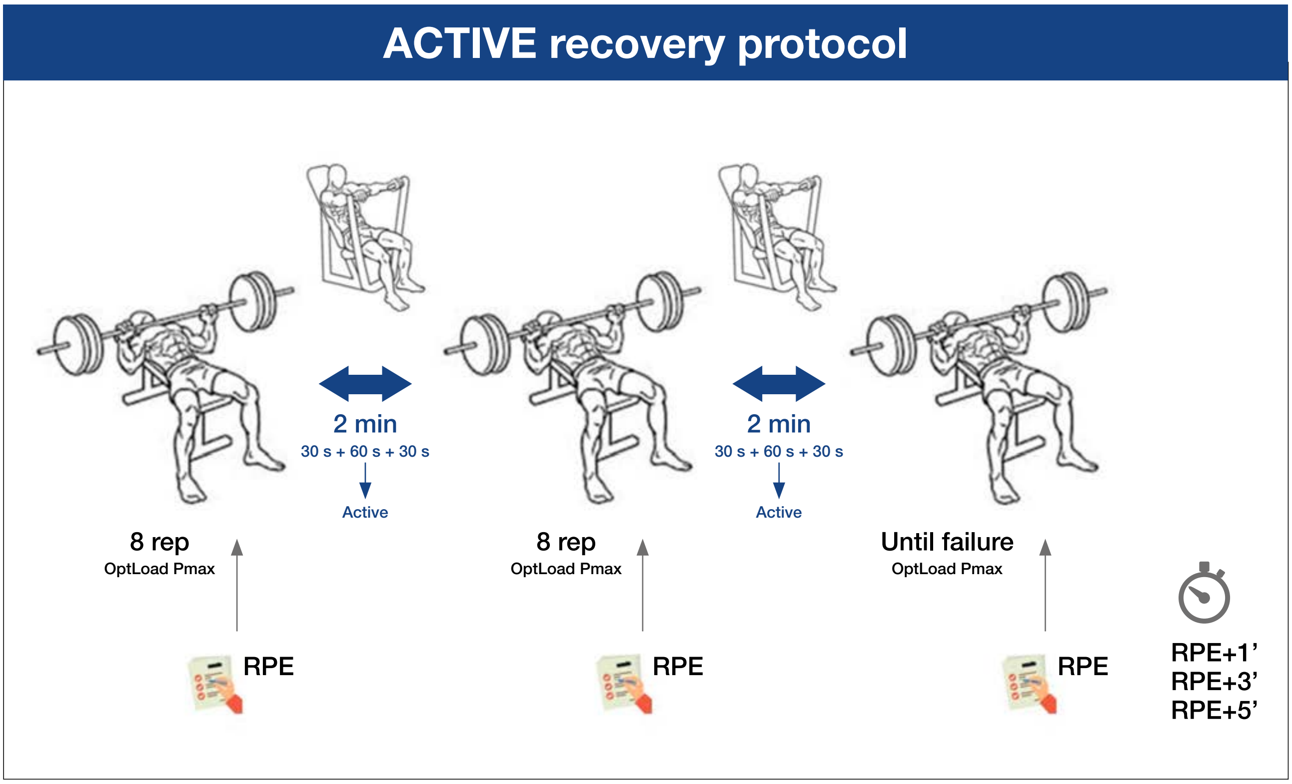

Figure 2
Measurement protocol with active recovery.
Source: Authors. Note. OptLoad Pmax: optimal load to develop maximum power; RPE: rate of perceived exertion.

Perceived exertion

The rate of perceived exertion (RPE) was recorded on a scale of 0 to 10 adapted for strength exercises, with a precision of .5 points allowed for the volunteers' responses. This was recorded at the end of each set (RPE 1, RPE 2 and RPE 3, respectively) and 1, 3 and 5 minutes after the last set until muscle failure (RPE post 1', RPE post 3' and RPE post 5', respectively).

Statistical analysis

All the data were analysed using the SPSS 20 statistical software (SPSS Inc., Chicago, IL, USA). The normality of each variable was verified using the Shapiro-Wilk test. A repeated-measures t-test was conducted to analyse the changes in the dependent variables associated with each protocol (ACT vs. PAS): mean propulsive power of the set (MPP, intraset loss of mean propulsive power rate (%Loss) and rate of perceived exertion (RPE). Statistical significance was set at a value of $p \leq .05$ with a confidence interval of 95%.

Results

All the data in the sample presented a normal distribution in terms of age, height, weight, body mass index (BMI), strength training experience and Pmax (Table 1).

Table 1
Characteristics of the sample.

	Total (*N* = 14)
Age (years)	22.5 ± 1.2
Height (cm)	177.9 ± 4.4
Weight (kg)	77.1 ± 6.3
BMI (kg/m2)	24.4 ± 2.0
Experience (years)	3.2 ± 1.9
Pmax (W)	705.2 ± 129.3

There were no significant differences in the MPP of each set between the two interventions (Table 2).

Table 2
Mean propulsive power (W) of each set in both interventions.

	ACT	PAS
Set 1	597 ± 107	590 ± 116
Set 2	581 ± 103	593 ± 91
Set 3	554 ± 94	564 ± 89

Note. ACT: active recovery protocol; PAS: passive recovery protocol.

The intraset loss of MPP (%Loss) was lower in ACT than in PAS in all three sets (13.34% vs. 18.84%, 15.97% vs. 17.67% and 13.38% vs. 17.53%, respectively), and these differences were statistically significant for the first and third sets ($p = .006$ and $p = .001$, respectively; $p = .084$ for the second set) (Figure 3).

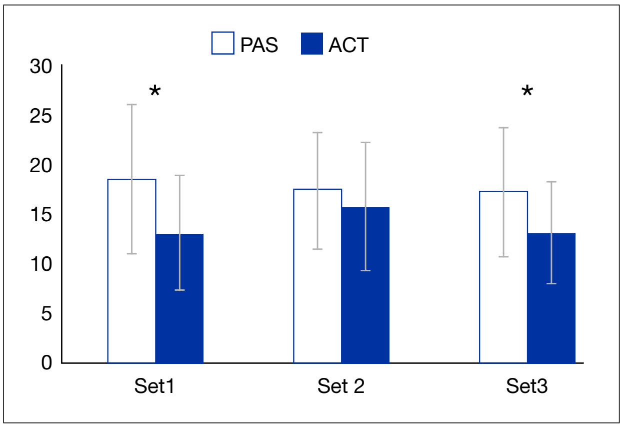

Figure 3
*Intraset loss of mean propulsive power (%) in both interventions (*p<.05).*
Note. ACT: active recovery protocol; PAS: passive recovery protocol.

There were no significant differences between both interventions in the nMR (45.7 ± 11.9 for the ACT protocol vs. 45.6 ± 11.6 for the PAS protocol).

The RPE was virtually the same in both protocols, although the result of the second set was significantly higher in ACT than in PAS (4.5 vs. 5.0, $p = .033$). Similarly, during the recovery after both protocols, the RPE tended to be slightly lower in ACT than in PAS during the measurements after 1, 3 and 5 minutes (9.2 vs. 9.3, 4.8 vs. 5.1 and 3.2 vs. 3.4, respectively), although these differences were not statistically significant (Figure 4).

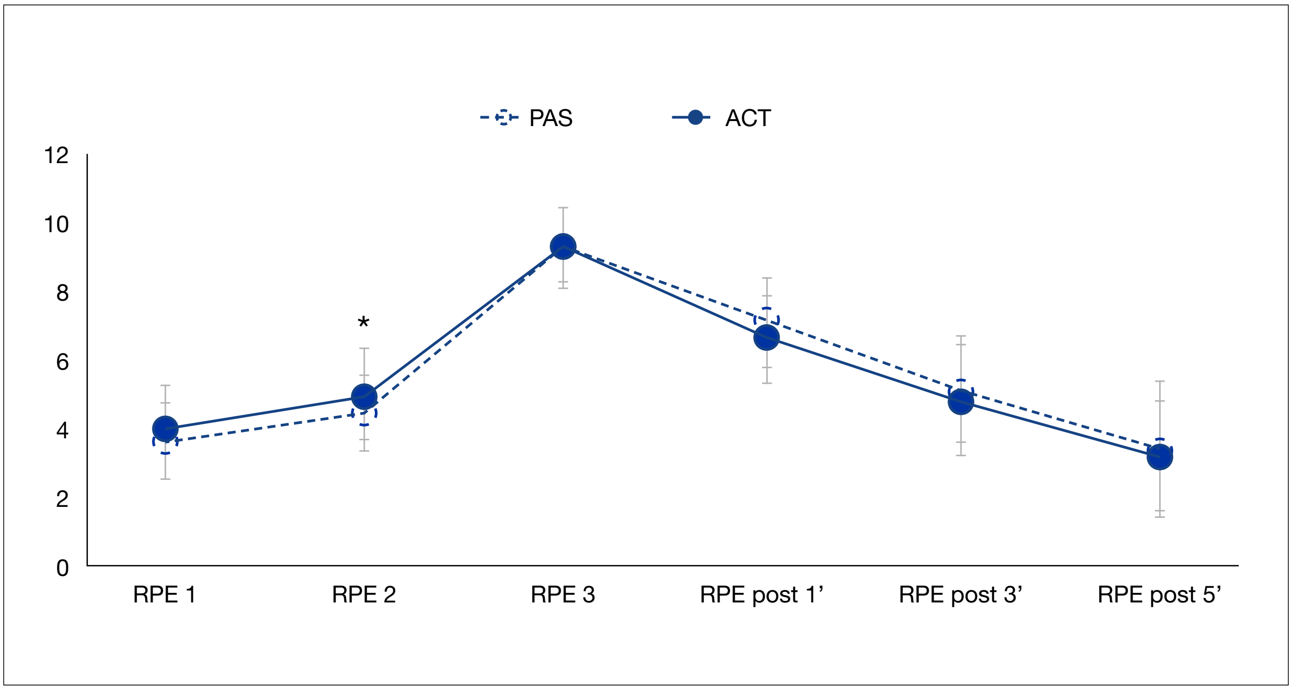

Figure 4
*Perceived exertion in both interventions (*p<.05).*
Note. ACT: active recovery protocol; PAS: passive recovery protocol; RPE: rate of perceived exertion.

Discussion

To our knowledge, this is the first study to analyse the effects of an active recovery using the same movement as the exercise evaluated on kinetic and perceptual variables in strength exercises. One of the most noteworthy aspects of our intervention is that the active recovery was well tolerated by all the participants and did not lead to any reduction in physical performance or perceived exertion.

Although we did not find significant differences between both interventions in the MPP of each set, there were differences between the protocols when we calculated the intraset loss of power, it transpiring that the active recovery protocol reduced the loss of power between successive sets compared to passive recovery; these differences were statistically significant in the first and third sets. Thus, knowing that less creatine kinase (CK) is produced when active versus passive recovery stimuli are compared (Gill et al., 2006), and that active stimuli promote oxygen perfusion and improve the recovery of the muscles involved in a given physical effort (Latella et al., 2019), we could hypothesise that our active recovery proposal could promote muscle tissue blood irrigation, with the consequent oxygen input, in turn fostering PCr resynthesis and therefore a greater involvement of the phosphagen system in successive sets.

In this same vein, Schoenfeld et al. (2019) conducted a study analysing whether a two-minute active recovery comprised of 30 seconds of voluntary isometric contraction of the muscle group involved in the exercise followed by 90 passive seconds would improve performance and structural adaptations compared to a passive recovery of the same length (two minutes), in an intervention three times a week over an eight-week period. The results showed that active recovery achieved higher hypertrophy in the lower limbs but not in the upper limbs, although this intervention did not show significant improvements compared to passive recovery in either strength or muscle resistance, which concurs with our findings about MPP and nMR. The authors assert that the greater degree of hypertrophy of the lower limbs associated with active recovery may be due to the fact that isometric contraction may lead to local blood vessel constriction, causing metabolites to accumulate (particularly $H+$), which would be conducive to a positive adaptation of acidosis buffering capacity; however, they did not measure metabolic stress markers and recommend that it be measured in future studies.

Other studies have evaluated different recovery strategies between strength training sets, including the systematic review by Latella et al. (2019). These authors identified 396 studies and ultimately analysed 26 that included different active recovery strategies between sets such as stretches, aerobic exercise, massage and self-myofascial release, vibration or electrical stimulation, among others. Their conclusions affirm that including active stimuli in recovery may increase the total number of repetitions that can be done; improve kinetic variables such as strength, power and speed; increase muscle activation; and reduce perceived exertion. However, it is important to note that the heterogeneity of the studies included in this review makes it difficult to draw general conclusions as to which active stimuli might be most appropriate for each strength training session. Furthermore, none of them studied an active recovery that included the same movement as that which is performed during training, as ours did. Nonetheless, these findings may help to corroborate the benefits of active versus passive recovery in strength training.

One of these active stimuli, aerobic exercise, was analysed by Mohamad et al. (2012), who conducted a crossover study to compare the acute responses of four types of interventions on different physiological and performance parameters. Although this active stimulus is different to our proposal in this study, their results show that there were no significant differences between groups or in kinetic variables, as in our case in MPP and nMR, as neither were there any in the kinematic variables or lactate concentrations. However, as the actual authors note, other possible important benefits of active stimulus in recovery periods between strength sets were not evaluated, such as the improvement in the resynthesis of energy substrates, the increase in anabolic hormone response and the lower loss of power during active recovery compared to passive recovery.

Another possible mechanism which could explain the lower intraset loss of power found by us with the ACT protocol compared to the PAS protocol may be due to the greater motor plate excitability induced by the active stimulus, which could influence the afferent pathway related to the critical threshold of peripheral fatigue and therefore the central command, thus facilitating muscle contractibility in successive sets during strength training (Allen et al., 2008).

While our study did not evaluate physiological parameters such as motor plate excitability, lactatemia or other muscle metabolic activity indicators, we do know that intense muscle activity causes PCr levels to decrease, which increases the concentration of inorganic phosphorous in muscle cells. Furthermore, ATP turnover and the increase in cytosolic metabolic activity increase the concentration of H+ ions, particularly in type-II fibres, in which pH could drop from 7.0 to 6.2 (Kent-Braun et al., 2012). Therefore, future studies addressing the effects of active recovery during strength training should also measure physiological parameters such as blood lactate levels, muscle oxygenation and CK levels.

Conclusions

In conclusion, our results demonstrate that given the same duration, active recovery may be more effective than passive recovery as a strategy to minimise loss of power and improve perceived exertion in successive sets during a strength training exercise in trained young men.

However, one of the main limitations of our study is that we did not record, for example, physiological or other parameters related to changes in motor plate excitability or possible injury mechanisms, so we cannot discern the mechanisms associated with this possible improvement. Similarly, another limitation lies in the actual experimental design, as including more sets could have shown the differences between the two recovery protocols in successive sets during a strength training exercise more clearly, as well as the use of a subjective scale to evaluate perceived exertion.

Future avenues of research should include and compare both physiological and performance parameters and analyse the effects of active versus passive recovery on the upper and lower limbs.

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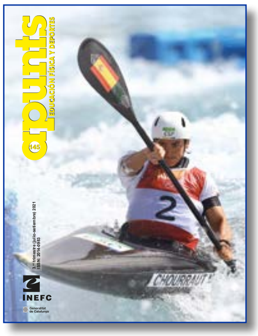

Acute:Chronic Workload Ratio. Exploration and Applicability in Women's Amateur Football

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Maialen Chourraut (ESP)
competing in Rio de Janeiro
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Whitewater Stadium.
Women's Kayak (K1) Semi-final.
REUTERS / Ivan Alvarado

Abstract

With the objective of analysing the possible relationships between the acute:chronic workload ratio modalities (both by consecutive workload averages - ACWR, and exponentially weighted moving average - EWMA) and injury rate in women's football, a quasi-experimental non-intervention study was performed of the ratios obtained in the 212 training sessions and matches held in the course of one season in a women's amateur football team ($N=17$). The variables used to calculate the acute load and chronic load ratios were the subjective ratings of perceived exertion (RPE) in relation to the internal load, each player's exposure time during the sessions as the external load (LOAD) and specificity (SP) in relation to the training schedule. The statistical analysis showed significant differences in the injury variable in the RPE EWMA (4:16, 7:28, 7:21), SP EWMA (4:16, 7:28, 7:21), LOAD EWMA (4:16, 7:28, 7:21) and LOAD ACWR (4:16, 7:28) ($p<.005$) ratios, as well as significant associations in the injury rate in the ratios shown, except in SP EWMA 7 28 ($p=.47$). The results might suggest the applicability of ACWR and EWMA in controlling load in women's amateur football in relation to injury rate, with the use of EWMA providing higher sensitivity..

Keywords: ACWR, EWMA, injury prevention, load control.

Introduction

Football has undergone changes in its development which have led the game's pace and intensity to increase (Bowen et al., 2017), a factor which may have led to the application of workloads verging on the tolerance limit to boost the possibilities of success (Bowen et al., 2017). In high-performance football, epidemiological studies describe an injury rate of approximately 9 injuries for every 1000 hours of exposure and a mean of two injuries per player and season, which could lead to the loss of up to 37 days a season (Ekstrand et al., 2011).

Football is an intermittent sport which combines high-intensity actions with recovery or low-intensity periods, also involving stringent physical and emotional demands (Malone et al., 2017). In view of these needs, managing training and competition loads is a tool that can be used to prevent injuries (Carey et al., 2017) by avoiding inappropriate loads that could increase the injury rate (Gabbett, 2018), ultimately preventing players from participating fully in future practice sessions or matches (Ekstrand et al., 2011).

In this regard, the use of workload control as an injury prevention tool continues to be conditioned by the technical staff's level of experience or understanding (Fanchini et al., 2018), reducing its possible effectiveness and applicability in highly complex work groups and environments (Gabbett, 2018).

Hulin et al. (2014) proposed a relationship between acute load and chronic load, which related (acute) physical fitness to (chronic) fatigue. The relationship between these two types of load (known in the literature as ACWR, acute chronic workload ratio) sets out to analyse the effects caused by training by comparing the athlete's training load to the load for which they may be prepared (Gabbett, 2018) based on the average accumulated load in the previous weeks, making it possible to obtain a sample of the dynamic representation of the athlete's preparedness (Malone et al., 2017). This ratio would quantify the accumulated amount of stress produced in a person through different training sessions and matches during a given time period (Hulin et al., 2014).

Workload is defined by external load (EL) and internal load (IL), as well as by specificity (SP) (Zamora et al., 2021). The variables for quantifying EL are related to the amount of work the athlete does, while IL refers to the relative physiological and psychological tension imposed on the athlete, whereby different individual internal responses are given to the same EL (Zamora et al., 2020). This response is determined, among other variables, by the way the EL is applied, the athlete's characteristics and the SP (Casamichana et al., 2012). In this sense, variables such as the number of players, the number of exercises, the presence or absence of goalkeepers and/or the presence or absence of goals give rise to a greater or lower degree of cognitive stimulation and conditional demands, and consequently to different effects on training levels (Casamichana et al., 2012).

To calculate the ACWR, an EL and/or an IL variable is used, which must be specific and replicable (Hulin et al., 2014). The EL variables used may be specific and replicable, such as exposure time (Sampson et al., 2016), shots (Hulin et al., 2014), accelerations (Carey et al., 2017), etc. For IL, some proposals use heart rate variability (Williams et al., 2017), although the rate of perceived exertion (RPE) is a useful variable for reporting physiological and psychological stress in different group modalities (Carey et al., 2017; Malone et al., 2017; Fanchini et al., 2018) and is more applicable than heart rate in football, given its intermittent nature (Rodríguez-Marroyo & Antoñan, 2015). The RPE, understood as the subjective response to a stimulus, has a multifactorial (Borg, 1990) and multidimensional perspective, and presents low variability (Casamichana et al., 2012), which is often used in football (Impellizzeri et al, 2020). With regard to SP, to the authors' knowledge, this variable is not addressed in the literature in relation to ACWR, even although it defines the complexity of the sessions and their possible relationship with injury rate, as it influences both IL and EL (Casamichana et al., 2012).

By interpreting the ACWR, this value's relationship with a higher or lower likelihood of injury can be interpreted, as in contactless injuries, in both Australian football (Carey et al., 2017) and in young élite footballers (Bowen et al., 2017). In professional football (Malone et al., 2017), players were seen to be less likely to sustain injuries when they were exposed to moderate-low to moderate-high acute:chronic ratios between values of .8 and 1.5. These load ratios could be used to optimise the daily management of the training load (Malone et al., 2017) and to improve injury prevention (Murray et al., 2016). Other authors, such as Williams et al. (2017), state that the ACWR moving average method does not accurately represent the nature of adaptations to training and fatigue. For this reason, they suggest updating the ACWR using the exponentially weighted moving average (EWMA). This method might favour the emphasis and sensitivity of the workloads towards the end of the calculation cycle (Sampson et al., 2016), which could be more applicable to the nature of the training, rendering it possible to control the progression of the loads and only their possible effect (Foster et al., 2018). In their study with Australian football players, Murray et al. (2016) report how EWMA presents greater sensitivity to injuries than ACWR during the preseason and season.

However, there is an ongoing debate on the reliability of these load control methods and their possible relationship with the injury rate. For contactless injuries, it may not be a reliable predictive tool (Fanchini et al., 2018) due to a predictive sensitivity below 25 % in all cases. For open sport systems, the prediction of injuries could not be limited solely to monitoring a number (Buchheit, 2016), as this fails to address the context in all its complexity. From a statistical standpoint, there are two possible errors. First, there is a connection between acute load and chronic load, meaning that acute load could be a useful predictor in itself without the need to standardise it with regard to chronic load, since the two indicators used are related to each other (Lolli et al., 2018). This connection may yield false correlations, as also occurs due to the proportion of events recorded with regard to the injuries sustained (and recorded), leading to an exponential increase in the magnitude of the acute workload and of the possible ratios found (Impellizzeri et al., 2020).

In this context, the objective of this study is to explore the applicability of the ACWR and the EWMA in managing load control as an injury prevention tool in women's amateur football.

Methodology

Design

A quasi-experimental non-intervention study was conducted by means of retrospective observation and an ex-post facto design, since the training sessions and injuries sustained by the different players in the team were monitored with a view to assessing the ratio between the ACWR and the EWMA of the different EL, IL and SP variables and the injuries leading to training session or match time loss injuries recorded during the observation period.

Participants

All the 212 training sessions and matches between August and May in the 2018-2019 season were monitored for the 17 players of a senior women's amateur football team that competes in the women's División Preferente in Catalonia, with training three days a week lasting an hour and a half and one match a week. A total of 3,460 events were recorded as a result of calculating the total number of players participating in each session. The participants had a mean age of 22.87 (± 4.8), a mean weight of 58.08 (± 4.75) kg and a mean height of 164.9 (± 3.93) cm.

All the team members (players, coaches and managers) were informed about the purpose of the study and provided their consent for their data to be used. The use of the data observed the criteria of the Declaration of Helsinki, Fortaleza revision (2013).

Recording of the variables

The independent variables recorded in this study were the RPE for IL, SP (Solé, 2008) and exposure time in relation to training and competition for EL. For the dependent variables, time loss injuries (Fuller et al., 2006) that prevented players from participating in training sessions and matches were related to the injury rate and different acute:chronic load ratios.

The eligibility criteria for stabilising the control variables were that the study participants had no associated cardiac problems, that the training level was amateur (> 2 days of training minimum and < 4 days) and that they were active at sample randomisation time. The observation conditions were always on the same field and at the same time during training according to the timetable established by the institution. Medical check-ups were always conducted by the same medical staff.

For the monitoring of the EL variables, each player's exposure time in training and matches was recorded; for IL, the RPE was obtained after each session using the Google Forms application, individually and 15 to 30 minutes after the end of each session, whereas specificity was calculated post-session, assigning a value to the tasks and considering whether the proposal was generic (1-2), general (3-4), targeted (5-6), specific (7-8-9) or competitive (10) (Solé 2008), yielding an average value of the session for the entire team (Table 1). These monitored values were transferred to a file where the ACWR (4:16, 7:21, 7:28) and EWMA (4:16, 7:21, 7:28) ratios were calculated individually for each one of the variables recorded (exposure time, RPE and SP). The first number in the ratios is the numerator or average accumulated acute load over this number of days, while the second number is the denominator or average accumulated chronic load over this number of days. The total number of injuries was also recorded. The data were collected and analysed by the team's physical trainer.

Statistical analysis

After a descriptive analysis of central tendency, the normality of the sample was determined. Subsequently, using the Mann-Whitney test, the possible significant differences between the different ratios analysed and the injury or no injury variable were observed. The values of the ratios were subsequently grouped together to determine the possible level of association with the injuries, bearing in mind the variables' qualitative nature, and using the chi-squared test. The data were considered significant starting at $p < .05$ (Figure 1). The program used to perform the statistical analysis was JASP (The JASP Team, Amsterdam, Holland) version 11.1 for Mac.

Table 1
Parameters and variables recorded during the sessions with the study participants.

Internal load	
Ratings of perceived exertion (RPE, Borg 1990)	Scale CR-10
External load	
Total volume	Exposure time (minutes)
Training programme	
Specificity (Solé, 2008)	Generic (level 1-2). General conditioning work (continuous run, bicycle, etc.) General (level 3-4). Individual strength and injury prevention task, circuits without a ball Targeted (level 5-6). Tasks without opposition. Technical circuits, waves and combined actions Special (level 7-8-9) from 1-on-1 to 10-on-10. Basic tactical situations, waves with opposition, position or possession play, and line work with opposition Competitive (level 10). Training matches 11-on-11 or official competitions
Injury rate	
Injury (Fuller et al., 2006)	Time loss injury

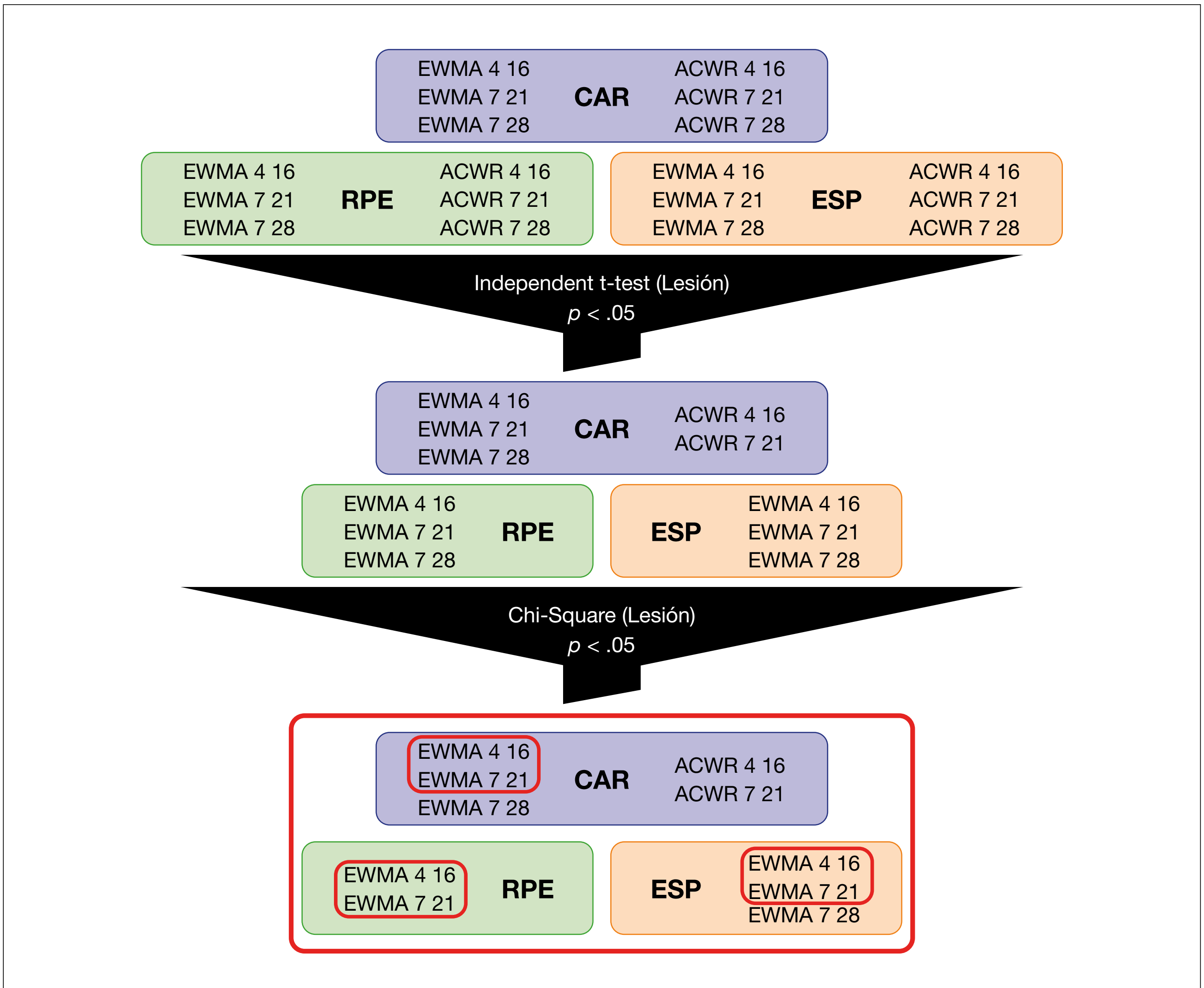

Figure 1
Statistical process with the analysed ratios of the study participants.

Table 2
Differences in the ACWR, EWMA ratios with regard to the injury or no injury variable in the study participants.

	W	*p*	Biserial correlation coefficient	95 % CI for the biserial correlation coefficient	
				Lower	Higher
RPE EW-MA 4 16	11820.00	< .01	-.42	-.60	-.19
RPE EW-MA 7 21	15437.50	.03	-.29	-.50	-.04
RPE EW-MA 7 28	14477.00	.05	-.26	-.48	-.01
RPE ACWR 4 16	45550.00	.59	.05	-.14	.24
RPE ACWR 7 21	39359.00	.93	.01	-.20	.21
RPE ACWR 7 28	37944.00	.40	.09	-.12	.30
SP EWMA 4 16	11645.50	< .01	-.43	-.60	-.21
SP EWMA 7 21	13877.00	< .01	-.36	-.56	-.12
SP EWMA 7 28	13223.00	< .01	-.33	-.54	-.08
SP ACWR 4 16	36537.50	.07	-.18	-.36	.01
SP ACWR 7 21	37067.50	.45	-.08	-.28	.13
SP ACWR 7 28	34943.50	.79	-.03	-.24	.19
LOAD EWMA 4 16	37657.00	< .01	-.28	-.45	-.09
LOAD EWMA 7 21	18206.00	< .01	-.59	-.71	-.43
LOAD EWMA 7 28	18364.00	< .01	-.53	-.67	-.35
LOAD ACWR 4 16	32760.00	.02	-.24	-.41	-.04
LOAD ACWR 7 21	29235.50	.02	-.25	-.43	-.04
LOAD ACWR 7 28	27421.00	.06	-.21	-.41	.01

Note. RPE: ratings of perceived exertion; SP: specificity; LOAD: load; EWMA: exponentially weighted moving average; ACWR: acute:chronic ratio. Significance $p < .05$

Results

The average values (+/- SD) per player obtained from the variables recorded during the 3,460 events were: for EL, 3365.226 +/- 1997.763 total minutes; for IL, an RPE of 6.305 +/- 1.689 per session; an SP of 6.852 +/- 2.302 per session; and a total of 12 time loss injuries were recorded, .011+/-.105 per player. The values of the ratios obtained were: RPE ACWR 4:16, 0.996 +/- 0.163; RPE ACWR 7:21, 0.998 +/- 0.121; RPE ACWR 7:28, 0.983 +/- 0.168; RPE EWMA 4:16, 0.962 +/- 0.502; RPE EWMA 7:21, 0.873 +/- 0.341; RPE EWMA 7:28, 0.857 +/- 0.366; ESP ACWR 4:16, 1.008 +/- 0.197; ESP ACWR 7:21, 1.003 +/- 0.143; ESP ACWR 7:28, 0.987 +/- 0.178; ESP EWMA 4:16, 0.988 +/- 0.496; ESP EWMA 7:21, 0.905 +/- 0.313; ESP EWMA 7:28, 0.885 +/- 0.342; CAR ACWR 4:16, 1.167 +/- 0.654; CAR ACWR 7:21, 1.067 +/- 0.463; CAR ACWR 7:28, 1.068 +/- 0.510; CAR EWMA 4:16, 0.977 +/- 0.582; CAR EWMA 7:21, 0.893 +/- 0.377; CAR EWMA 7:28, 0.885 +/- 0.411.

Statistical analysis

Given the non-normality of the sample, the Mann-Whitney test allowed us to determine significant differences ($p < .05$) with regard to the injury or no injury variable for the LOAD ACWR ratios and for the RPE EWMA (4:16, 7:28, 7:21), SP EWMA (4:16, 7:28, 7:21), LOAD EWMA (4:16, 7:28, 7:21) and (4:16, 7:28) (Table 2) ratios, with an effect magnitude of between -.586 and -.262. No significant differences were found between the different positions analysed.

Subsequently, the values of the different ratios were grouped into different ranges with a difference greater than 1. The chi-squared test showed associations of all the previous ratios with injuries ($p < .05$) in LOAD ACWR and in RPE EWMA (4:16, 7:28, 7:21), SP EWMA (4:16, 7:21) and LOAD EWMA (4:16, 7:28, 7:21) and (4:16, 7:28), but not SP EWMA 7 28. With regard to the value of the ranges of the ratios obtained, the results show an association between the number of injuries and under the lower range of .7-.8, and of the upper range of 1.3-1.4, except for LOAD ACWR 4 16 (1.1) and LOAD EWMA 4 16 (1.2) where the upper range is 1.1 and 1.2, respectively (Table 3).

Table 3
Association for the ranges of ACWR and EWMA and the injury/no injury variable for the study participants.

Acute:chronic load ratio	X^2	Acute:chronic workload ratio ranges
RPE EWMA 4 16	< .01	< .8; .8-1.4; > 1.4
RPE EWMA 7 21	< .01	< .8; .8-1.3; > 1.3
RPE EWMA 7 28	.09	--
SP EWMA 4 16	< .01	< .8; .8-1.4; > 1.4
SP EWMA 7 21	.03	< .8; .8-1.3; > 1.3
SP EWMA 7 28	.04	< .8; .8-1.3; > 1.3
LOAD ACWR 4 16	.02	< .8; .8-1.1; > 1.1
LOAD ACWR 7 21	.03	< .8; .8-1.3; > 1.3
LOAD EWMA 4 16	.02	< .7; .7-1.2; > 1.2
LOAD EWMA 7 21	.00	< .7; .7-1.1; > 1.3
LOAD EWMA 7 28	.00	< .7; .7-1.3; > 1.3

Note. RPE: ratings of perceived exertion; SP: specificity; LOAD: load; EWMA: exponentially weighted moving average; ACWR: acute:chronic ratio. Significance p <. 05.

Discussion

This study's main finding of was the possible identification of acute:chronic workload ratios most highly related to injury rate. It transpires that EWMA may have a greater association with the number of injuries than the ACWR for both EL and IL, and even for SP, as well as in ratios for short (4:16) and longer periods (7:28). These results might concur with those presented by Foster et al. (2018), who state that using the EWMA may be more reliable for injuries, given that it presents greater sensitivity of calculation than the traditional ACWR (Griffin et al., 2020; Murray et al., 2016).

With regard to the variables used, we observed how the RPE identified as the IL variable in all the ratios established for EWMA could point to significant associations with the injuries of the players analysed. These results are related to those of Malone et al. (2017) and Fanchini et al. (2018), although these authors report their use of the ACWR with workload values resulting from the product of the EL by the IL, not with a single variable, as in our study and also as other authors present (Foster at al., 2018). Using this same method, albeit in a different sport (tennis), the use and analysis of the RPE as the sole variable for quantifying load may be a good indicator to use in calculating the acute:chronic ratio because of its significant relationship with the injury rate (Myers et al., 2019). Bearing in mind the scheduling of the training, SP returns significant associations through the use of the EWMA for the three types of variables (IL, EL, SP). This could provide further information about how the periodisation of an exercise similar to the actual match setting may be important in relation to how the player copes with the workload and its potential relationship with any injuries that may be sustained.

Both ACWR and EWMA, irrespective of whether they refer to EL, IL or SP, presented significant associations with regard to injuries, which could tell us that the acute:chronic workload ratio may be a valuable tool in load control (Griffin et al., 2020), taking the possibilities or the resources of each work group into account. Nevertheless, it is essential to nuance that this possible association is not synonymous with predictability, an interpretation that could lead to erroneous scientific conclusions (Griffin et al., 2020). In this context as well, the increase in the association of the ratios may be due to the connection of the different variables (EL and IL) that would define the load (Lolli et al., 2018), although this did not occur in the case presented here, since only one variable was used to calculate the ratio (EL, CI or SP) (Griffin et al., 2020).

With regard to the ratios, the three options proposed (4:16, 7:21 and 7:28) could also present significant associations, although the most significant ones were related to the load in long ratios (7:21 and 7:28), which are the ones used most often in group sports (Griffin et al., 2020). In a sport involving competitions every seven days, the use of this as an acute and chronic window might be justified as a tool applicable to this scheduling and competition model. Even so, and in contrast with this, significant associations can be seen through the use of four days as an acute window in all the variables for EWMA 4:16 and the EL ACWR 4:16 variable, which might be an indicator of the importance of managing acute loads and their possible influence on the injury rate (Carey et al., 2017) in this specific context.

On analysis of the groupings obtained, the ranges of the values of the ratios that might be associated with injuries fluctuate between .7-.8 in the lower range and 1.3-1.4 in the upper range. According to the initial proposal by Hulin et al. (2014) for EL or Gabbett (2018) (in ratios calculated for EL by IL), the range of 0.8 to 1.3 may lie in the lowest risk zone, given that that acute and chronic workload are approximately at the same magnitudes and there is therefore no overload or lack of training. The results do differ from other proposals in which RPE is used (Malone et al., 2017), where the ranges of the lowest risk of injury lie between the values of 1.00 and 1.25. In any event, the different options presented might be indicators of the specificity of each one of the variables, ratios and ranges in each sport and each team analysed. No value has sufficient magnitude to determine the boundary between the risk of injury or no injury. The cause of an injury is multifactorial and the complexity of the context is not congruent with this attempt at simplification (Gabbett, 2018).

The main limitation of this study is that kinematic variables are not monitored, since recording them would have made it possible to create a more justified profile of the values obtained in relation to EL. In turn, the fact that only time loss injuries were recorded reduces the number of records obtained, interfering in the magnitude of associations shown (Lolli et al., 2018), or preventing us from evaluating the possible influence according to playing position. Although it is a novel approach, it is essential to remember that using SP as a training programme element implicitly includes a subjective and random aspect. By exploring it, we have been able to assess its ultimate applicability. The RPE is a subjective value that may also have certain limitations (Impellizzeri et al., 2020; Buchheit, 2016), although its applicability in women's sport has also been confirmed (Piedra et al., 2020), and it has been used to calculate ACWR, presenting significant associations with injuries (Griffin et al., 2020). In any event, the limitations presented are inherent to amateur sport, in which limited economic resources preclude the use of certain technologies. For this reason, longitudinal explorations and studies are needed in the training context to assess their applicability.

In conclusion, in this specific context, acute:chronic workload ratios may be an applicable tool for controlling load in women's amateur football, given the possible relationship with the injury rate. The results yield a more positive assessment of the EWMA in view of its greater sensitivity. Finally, in relation to ratio ranges, the 0.8 to 1.3 range could be the value associated with the lowest injury rate. However, the interpretation of the results and their possible applicability should be limited to the contexts analysed.

Practical applications

Physical activity and sports sciences professionals, regardless of the available technology or the number of team members, can calculate and interpret load dynamics and indirectly improve the training and injury prevention process.

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Conflict of interests

The authors declare that they have no conflicts of interest and that no financing was received from any private or public entity for the project.

Future outlook

To continue this line of analysis, in future studies it might be interesting to observe whether the ratios also present associations by different types of injuries (Fuller et al., 2006). Similarly, including a kinematic study with the objective of relating it to the external load of training and player positions could be worthwhile.

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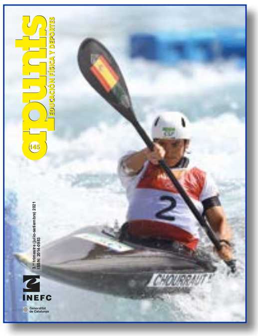

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Competitive Balance in Male European Rink Hockey Leagues

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Abstract

The interest in competitive balance in different team sports has increased over time. However, hitherto, scant research has been conducted into minority sports, such as rink hockey. With these circumstances in mind, the primary objective of this study was to quantify the competitive balance in different European professional rink hockey leagues (Spain, Portugal, Italy and France) and to compare the results. The sample was comprised of 7,394 rink hockey matches (2,284 in the Spanish league, 1,996 in the Portuguese league, 1,794 in the Italian league and 1,320 in the French league) played between the 2009-2010 and 2018-2019 seasons. To determine competitive balance, the Accumulated Points Difference (APD) was calculated and a One Way ANOVA followed by the Tukey Post Hoc multiple comparison test was used. The results showed that the French league is the most balanced championship (68.94% ± 6.39), followed by the Spanish league (71.93% ± 10.77). The Portuguese (75.31% ± 5.48) and Italian leagues (75.16% ± 8.55) presented higher APD values, indicating that some teams enjoyed a more significant advantage. The analysis of competitive balance could provide a better understanding of this effect in rink hockey. This metric can help coaches and practitioners to tailor training programs better and also help governing bodies to understand competitive parity in every European league. In this regard, in some cases, changes may need to be made to the format of the competition to make it more balanced.

Keywords: competitive advantage, minority sports, outcome uncertainty, performance analysis, rink hockey, team sports.

Introduction

In recent years, the growing interest in sports performance analysis has also led to an increase in the number of studies dealing with match variables in team sports. Rink hockey, also known as roller hockey or quad hockey, is no exception, and in the last few years the number of studies addressing this sport has grown considerably. Thus, home advantage (Arboix-Alió et al., 2020; Arboix-Alió & Aguilera-Castells, 2019), scoring sequence (Arboix-Alió et al., 2019; Arboix-Alió & Aguilera-Castells, 2018), the influence of opponents' offensive play on goalkeeper performance (Sousa et al., 2020), the conditional response according to court dimensions and number of players (Fernández et al., 2020) or individual set-pieces (Arboix-Alió et al., 2021; Trabal, 2016; Trabal et al., 2020) had been studied in specific rink hockey contexts. One of the most relevant factors associated with this outcome is competitive balance (CB), defined as the degree of parity among teams (Gómez-González et al., 2019).

Competitive parity has also become a relevant topic in sports economics. Unlike other contexts, sport, and more particularly professional leagues, requires a certain degree of CB to achieve maximum benefits (Lee et al., 2018). CB reflects both teams' likelihood of winning the competition (García-Unanue et al., 2014). Therefore, the study of CB for each professional league is relevant, because a higher balance usually results in greater fan interest, leading to better attendance and increased television audiences (Soebbing, 2008). This increased interest also generates greater profits for teams (Levin & Bailey, 2012; Levin & Mcdonald, 2009).

CB can be interpreted as the degree of uncertainty as to a team's position at the end of the season. More specifically, Szymanski (2003) distinguishes between three degrees of uncertainty. Firstly, game uncertainty, when both teams have a chance of winning. Secondly, the uncertainty of a specific season, when several teams have the potential to be placed in the top positions or make the playoffs. Finally, the uncertainty of a league or competition, with different teams winning the championship over several years.

Scientific research has used several methods to measure CB, focusing mainly on regular season analysis (García-Unanue et al., 2014). Of these measurements, the Competitive Balance Ratio for perfect competitiveness (Humphreys, 2002), the Gini coefficient (Schmidt, 2001), the concentration ratios of victories for the first five teams (Naghshbandi et al., 2011), the Accumulated Points Difference (Gasparetto & Barajas, 2016) or the Herfindahl-Hirschman Index, used to measure CB in professional sports leagues (Owen et al., 2007), have been used in the studies mentioned above. Furthermore, adapted versions allowing comparisons between leagues with a different number of teams and within leagues with a variable number of teams over time could be considered (Zambom-Ferraresi et al., 2018).

The effect of CB has been studied in many sports competitions in different countries (Kringstad, 2020; Zheng et al., 2019), on the one hand for individual sports such as cycling (Bačik et al., 2019), table tennis (Zheng et al., 2019) or athletics (Mills & Winfree, 2018), and on the other for team sports such as basketball (García-Unanue et al., 2014), ice hockey (Bowman et al., 2018), rugby (Hogan et al., 2013), handball (Hantau et al., 2014), baseball (Soebbing, 2008) or soccer (Naghshbandi et al., 2011; Ramchandani et al., 2018). Nevertheless, to the best of our knowledge, few studies address this topic in rink hockey. Only Arboix-Alió, Buscà, et al. (2019) have analysed CB between male and female teams in the Spanish and Portuguese leagues. Thus, this study's primary objective was to analyse the CB of four top male European rink hockey leagues (Spain, Portugal, Italy and France) using the Accumulated Point Difference and to compare each league's results.

Methodology

Materials and methods

Sample

This study's dataset consisted of ten years of box-scores (from the 2009-2010 season to the 2018-2019 season) collected through the www.hockeypista.it open-access website. Match data were double-checked and validated using the www.okcat.cat independent website. 7,394 rink hockey matches were analysed to carry out the study: OK Liga (Spanish league; 2,284 matches), Serie A1 (Italian league; 1,794 matches), Divisao (Portuguese league; 1,996 matches) and N1 Elite (French league; 1,320 matches). These rink hockey leagues have a similar fixtures schedule; all the teams play against each other once at home and once away during the season. All matches involve a home and away team. Only regular-season matches were included in the sample. The scoring system of all the rink hockey leagues analysed was: 3 points for a win, 1 point for a draw and 0 points for a loss.

Variables

The Accumulated Point Difference (APD) was used as an indicator of CB. The APD calculates the sum of the point differential among participants (Gasparetto & Barajas, 2016). These differences are computed by subtracting the points obtained by the runner-up from the champion's total points. This operation is repeated successively until the point difference between the second-last team and last teams is calculated.

Table 1
Descriptive analysis of APD values for each league and season. Total values are expressed as Mean ± SD.

Season	Spain APD (%)	Portugal APD (%)	Italy APD (%)	France APD (%)
2009-2010	70.00	72.22	76.92	74.24
2010-2011	57.69	71.11	82.05	74.24
2011-2012	70.51	79.76	73.08	74.24
2012-2013	70.00	77.78	88.46	57.58
2013-2014	91.11	64.44	83.33	66.67
2014-2015	85.56	83.33	76.92	64.64
2015-2016	63.33	75.64	57.69	62.12
2016-2017	58.89	75,00	70.83	71.21
2017-2018	75.56	80.77	71.79	77.27
2018-2019	76.67	73.08	70.51	68.18
TOTAL	71.93 ± 10.77	75.31 ± 5.48	75.16 ± 8.55	68.94 ± 6.39

Note: APD = Accumulated Point Difference.

Thus, the maximum imbalance would be calculated as follows:

$$\text{Imbalance}_{max} = 6 * (N - 1)$$

Therefore, the formula created from the APD method is presented below:

$$\text{APD} = \left(\frac{\sum_{i=1}^{N} (\text{TP}_{i=1})}{\text{Imbalance}_{max}} \right) * 100$$

Where N is the number of participating teams and TP is the total points of each club at the end of the tournament. In addition, the Average Position (AP) of the teams winning the championship in each league over the ten seasons studied was calculated.

Statistical analysis

The Shapiro-Wilk test was used to confirm that the data were normally distributed, thus permitting parametric tests. Descriptive statistics were performed to calculate mean ± SD and frequencies. Group comparison was performed using a two-way (league and APD) analysis of variance (ANOVA), followed by Tukey's Post Hoc multiple comparison test. Statistical analyses were performed using SPSS (Version 20 for Mac; SPSS Inc., Chicago, IL, USA) and statistical significance was set at $p < .05$.

Ethical considerations

Since the study was performed in an official competition open to the public, according to the American Psychological Association's ethical requirements (2002) the athletes' informed consent was not required.

Results

Table 1 presents the descriptive statistics and percentages of the APD from all the matches in the different competitions between the 2009-2010 and 2018-2019 seasons. The competition with the lowest APD value, and consequently the most balanced one, was the French league (68.94%±6.39). Although a significant main effect of the league on the APD index was not found [$F_{(3,32)} = 1.412$ $p = .255$], and this difference was not statistically significant ($p > .05$), the difference was almost 7% for the Portuguese league (75.31%±5.48) and the Italian league (75.16%±8.55). The Spanish league had a closer APD value when compared to the aforementioned competitions with 71.93%±10.77 (Figure 1).

The evolution in the APD value over the ten seasons analysed fluctuated less in the Portuguese and French leagues (Figure 2). On the contrary, the Spanish league presents greater variability in some seasons, with an APD value of 91.11%, compared to 57.69% in others.

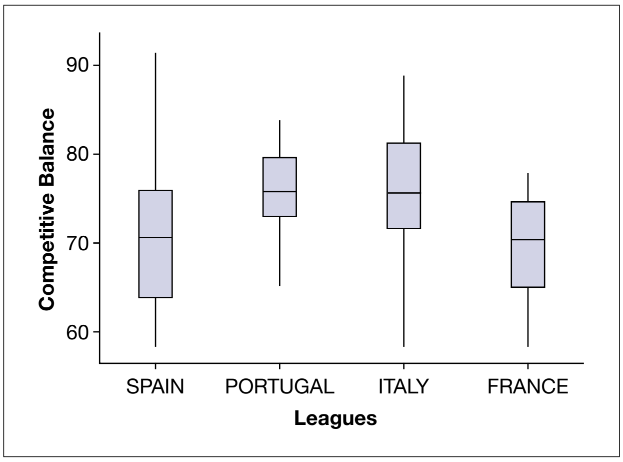

Figure 1
Comparison of Accumulated Point Difference values by league.

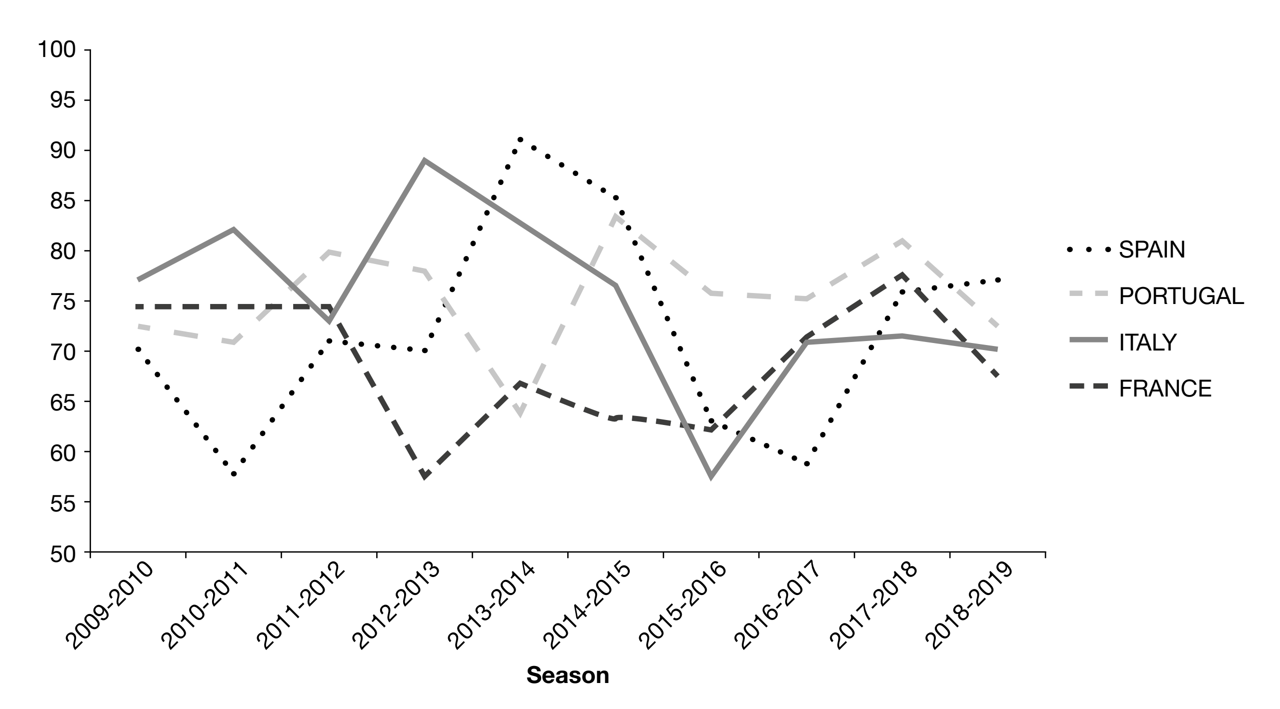

Figure 2
Evolution of Accumulated Point Difference values over time.

Table 2
Winning teams, number of championships and average position from the 2009-2010 to the 2018-2019 seasons.

Spain			Portugal			Italy			France		
Club	C	AP	Club	C	AP	Club	C	AP	Club	C	AP
FC Barcelona	8	1.3	FC Porto	5	1.7	Forte Dei Marmi	4	4	HC Quévert	5	1.7
HC Liceo	1	2.1	SL Benfica	3	2.2	Amatori Lodi	3	3.6	La Vendéenne RH	2	3.33
Reus Deportiu	1	3.4	Sporting CP	1	5.42	Hockey Valdagno 1938	2	4.2	US Coutras	2	4.2
			AD Valongo	1	5.7	Viareggio	1	3.5	SCRA Saint-Omer	1	2.8

Note: C = Championships won; AP = Average Position.

Table 2 shows the clubs that win the national championship and their average position over the ten seasons analysed. It points to the dominance of some clubs in their respective national leagues. Teams with an average value near 1 or 2 were always close to the leading top positions, even if they did not win the championship in every competitive season.

Three clubs won the championship at least twice in the course of the ten seasons analysed in the French and Italian leagues. While, in the Portuguese league, FC Porto and SL Benfica won the championship two or more times (five and three, respectively), whereas FC Barcelona won eight championships in the Spanish league.

Discussion

This study's primary objective was to analyse the CB of several male European professional rink hockey leagues. The results showed that the French league achieved a lower APD value and that consequently it may be considered the most balanced competition.

To the best of our knowledge, this is the first comparative study about CB in European rink hockey leagues; very little information on the matter was found in the literature for the purpose of comparison with these findings. However, a comparison of these findings with those of Gasparetto and Barajas (2016) on APD in professional football leagues (between 2006-2007 and 2013-2014 seasons) yields certain differences between these sports. First and foremost, the APD values were lower in all the football leagues analysed than in the rink hockey leagues. The APD values in the Spanish (55.59%), French (47.7%), Italian (54.28%) and Portuguese (58.89%) professional football championships presented a higher competitive balance than professional rink hockey. One possible explanation for this might be that rink hockey is a less-intensively played sport and has fewer economic resources than football. For this reason, the different budgets of the teams competing in the same league would make for greater heterogeneity, with professional and semi-professional athletes playing in the same competitions.

With regard to the evolution of CB values over time, it should be noted that the French league seems to fluctuate less, whereas the Spanish, Portuguese and Italian leagues present greater variability. The APD value ranges from 77.27% to 57.58% in the French league, whereas in the Spanish, Portuguese and Italian leagues they range from 91.11% to 57.69%, from 83.33% to 64.44% and from 88.45% to 57.69%, respectively.

As for the clubs that won a national championship in the course of these ten seasons, variability in the Spanish and Portuguese leagues is lower. The supremacy of FC Barcelona in the Spanish league is virtually absolute, as it won eight of the ten leagues analysed. Apart from FC Barcelona (HC Liceo and Reus Deportiu, with 2.1 and 4.4 AP, respectively), the AP of teams that have won a championship showed that the same teams consistently occupy the leading positions. Although this supremacy is not as evident in the Portuguese league as in the Spanish league, there is also a similar trend, and FC Porto and SL Benfica are vastly superior in terms of number of championships won (five and three, respectively) and in AP (1.7 and 2.2). These clubs' patent superiority over the other teams could be attributed to financial reasons, as they belong to football clubs. This phenomenon, called the "drag effect" (Zambom-Ferraresi et al., 2018), affords some rink hockey teams a major advantage over others that do not belong to prominent professional structures. These other teams do not benefit from state-of-the-art facilities or well-paid staff. Another aspect to be considered is the tradition and history of these clubs, in which football was usually the founding sport. Rink hockey clubs with a long-standing tradition enjoy greater support from institutions and sport governing bodies. Finally, the crowd effect must also be considered, as these teams have many supporters. Indeed, previous football research reported that match attendance can significantly determine both dynamics and outcomes (Sors et al., 2020). All of these facts could explain why the same teams have won several championships in the last ten seasons in the Spanish and Portuguese leagues.

This research has certain limitations that must be acknowledged and be addressed in further research. Firstly, it only used the APD method to calculate CB. Secondly, further research could study CB in other rink hockey competitive contexts, such as in different divisions (1st Division, 2nd Division) or in different competitions (Champions League, WS Europe Cup). Expanding the study with more seasons and an analysis of CB at match, season and competition level and including spectator opinions, could be a starting point for adding greater weight to these conclusions. Additionally, identifying the key factors that define success in one sports league rather than others may help to transcend the traditional competitive balance indicators.

Conclusions

Our results identified CB values in four main European rink hockey leagues. According to these findings, the French league presents the lowest APD value and is consequently the most balanced competition in the sample. To the best of our knowledge, this is the first study to compare CB among different European rink hockey leagues. No previous studies have performed this comparison for an extensive set of seasons to obtain sound results. Consequently, this research contributes new knowledge that improves our understanding of the CB effect in general and in rink hockey in particular. This research is therefore expected to contribute to the theoretical and methodological development of the topic.

The analysis of the effect of CB in professional rink hockey leagues may be of interest to Rink Hockey Federations and associations. Quantitative data about CB in each league can help decision-makers to make changes to promote more balanced championships (i.e. establish a wage cap, change the competition format, including a playoff system or a final four instead of a regular league) and to increase attendance figures.

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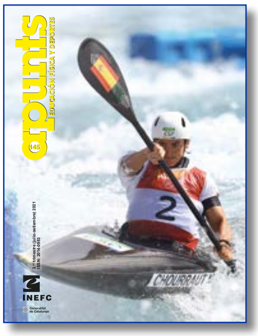

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Systematic Review of Social Influences in Sport: Family, Coach and Teammate Support

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Maialen Chourraut (ESP) competing in Rio de Janeiro Olympic Games (2016), Whitewater Stadium. Women's Kayak (K1) Semi-final. REUTERS / Ivan Alvarado

Abstract

The objective of this study was to analyse the scientific publications on the influence of social agents in sport, to identify the types (emotional, informative, tangible) and levels (positive, indifferent, negative) of social support provided to athletes by family members, coaches and teammates. This systematic research was completed by means of a search on the PsycInfo, ProQuest, SportDiscus, Scopus and Web of Science databases and reference lists of systematic reviews on social support in sport. The PRISMA checklist was used to conduct the study, and the study quality analysis was implemented using the STROBE Statement. The PECOS criteria were used in the eligibility of studies found based on the terms applied in the search strategy. The 31 studies selected examined the perception of the three stages of sports training (diversification, specialization, investment) of team and individual sport athletes. The main conclusion is that advances in research into social support have generated a diverse body of evidence, revealing a focus on the analysis of family social support. Family members were identified as the most prevalent social support providers, offering athletes unique forms of emotional, informative and tangible support from positive and negative. Coaches played a significant role in emotional and informative support and teammates in emotional support. It is concluded that positive levels of emotional, informative and tangible support from social agents are key in solidifying athletes' desire to stay in and prolong their involvement with the sport.

Keywords: interpersonal relationships; knowledge; social support; systematic review.

Introduction

Interpersonal relationships are one of the main factors that determine the quality of athletes' experiences in sport (Coutinho et al., 2018). Accordingly, understanding social influences has been considered one of the most relevant topics in predicting sports performance (Goldsmith, 2004), which is influenced by the result of interaction with social agents in addition to experiences and quality training, as well as by the athlete's innate talent.

In terms of social support in sport, athletes have three main sources of influence as their athletic career progresses: family members; coaches and teammates. These social agents form a complex and multifaceted social network that may not influence or may have positive and/or negative effects on athletes' sports experiences (Côté et al., 2003; Côté et al., 2016; Sheridan et al., 2014), as they contribute to the creation of a motivational climate, defined through their behaviours, values, attitudes and support (Camerino et al., 2019; Puigarnau et al., 2016) that affects the way athletes interact and perceive their involvement with sport (Atkins et al., 2013). For this reason, the sequence explains the three main social agents and how they contribute to the involvement of athletes in sport.

Social support

"Social support" is a term commonly used in the literature to describe a group of distinct, albeit interrelated, phenomena (Goldsmith, 2004). In the context of sports, it is a multidimensional construct that has been employed to describe the overall quality of relationships through perceived, available or received support and the individual's social network (Rees & Hardy, 2000).

There are several types of social support (Goldsmith, 2004), although three specific types have been suggested as being particularly relevant in sport: emotional; informative and tangible (Cutrona & Russell, 1990; Holt & Dunn, 2004;). Emotional support refers to forms of care and encouragement, leading a person to feel loved and protected by others (e.g., motivation and affection). Information support includes receiving information and advice about different situations (e.g., feedback and tips), while tangible support includes concrete assistance received (e.g., logistical and financial support) (Holt & Dunn, 2004; Cutrona & Russel, 1990). Thus, the positive development of athletes through sport will depend on their relationships with social agents, the type of support and how it is perceived by the athlete.

Social agents

The family is regarded as a primary socializing agent through which children develop their own identities and learn the norms and values of the society in which they live (Kubayi et al., 2014). Most of the time, it is the family that provides the child with the first opportunity to play a sport and also has a significant impact on the child's decision to pursue or give up a sport (Nunomura & Oliveira, 2013). Therefore, from the moment the child takes up a sport, through to their initial accomplishments, parents bring a significant influence to bear upon their sporting career (Dunn et al., 2016; Sheridan et al., 2014).

In addition to the family, the sports coach occupies a position of power and leadership that is seen as central to determining athletes' experiences (Kassing et al., 2004; Mora et al., 2014; Nascimento Junior et al., 2020). As young athletes engage more systematically in sport, coaches become a substantial source of influence, while parents gradually move more into the background, playing a less directive role in their children's sports (Pérez-González et al., 2019; Wylleman & Lavallee, 2004). Thus, the support and the quality of the coach-athlete relationship have been regarded as core elements in developing a career in athletics (Jowett & Cockerill, 2003) and consequently a key aspect in achieving success in sports (Riera et al., 2017).

Despite the significant influence exercised by the family and the coach, there comes a time when youth athletes start to spend more time with their peers in the sporting environment. During this period, usually in adolescence, peer influence becomes increasingly important to athletes (Côté et al., 2016; Mora et al., 2014) in sport and in other areas of their life (Holt & Sehn, 2008; Sanz-Martín, 2020; Scott et al., 2019). Teammates constitute a social network that enables the sharing of goals, lifestyles, difficulties and building a sense of relationship among members, besides the potential for providing positive and/or negative psychosocial experiences throughout involvement in sport (Fraser-Thomas & Côté, 2009; Scott et al., 2019), influencing the athlete's engagement and their decision to continue to do or give up sport (Fraser-Thomas et al., 2008a).

Based on the perspective of social support in sport, scientific production about social influences has been seen to grow considerably over the years (Cranmer & Sollitto, 2015; Folle et al., 2018; Keegan et al., 2010). In general, studies have emphasized that athletes are more likely to achieve positive results (high performance, a successful sports career) when they are encouraged and supported by positive feedback and are supported by family members and coaches that encourage autonomy (Dunn et al., 2016) and by teammates who assist in their personal and moral development (Valero-Valenzuela et al., 2020).

In addition to social influences, sports development models have been put forward in order to glean a better understanding and determination of the involvement of young people in sport, including the Sports Participation Development Model - DMSP (Côté, 1999; Côté et al., 2003). The DMSP proposes that young people develop through stages with specific characteristics and sequential age groups. These stages are related to initial diversification into sports activities (up to 12 years), specialization in one sport (13 to 15 years) and investment in a specific sport focusing on performance (over 16 years) (Côté et al., 2003).

Although important research has been conducted into social influences, there is a scarcity of systematic review studies that offer an integrative view of existing empirical knowledge, focusing on support from the three main social agents (family members, coaches and teammates) and the type (emotional, informative and tangible) and the level (positive, indifferent and negative) of the support provided to athletes. Thus, as already noted by systematic reviews on the topic (Bremer, 2012; Sheridan et al., 2014), such studies broaden our understanding of the topic and provide an opportunity for researchers to share available evidence by identifying appropriate theories to develop future research directions and intervention strategies, as well as to raise awareness of the range of research methods employed in the area of study and detect what research is still needed.

In this scenario, this review sets out to analyse scientific publications on the influence of social agents on sport to identify the types and levels of support provided to athletes by family members, coaches and teammates. In accordance with this purpose and with the literature on the subject, four hypotheses were formulated for this study: a) family members provide mostly emotional and tangible support; b) coaches provide predominantly informative support; c) teammates provide greater emotional support; and d) support from social agents is perceived predominantly by athletes as positive.

Methodology

Research protocol

For the preparation of this systematic review, the criteria recommended by the Declaration Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA; Moher et al., 2009) were followed, which provide a guideline for systematic reviews and meta-analyses (Moher et al., 2015). To increase transparency in the review process and to disseminate and reduce the unintended duplication of systematic reviews, the protocol of this research was registered in the International Prospective Register of Systematic Reviews (PROSPERO - CRD42019114096) database. Registration gives entitlement to the permanent documentation of 22 mandatory (plus 18 optional) items on the preparation and conduct of a systematic a *priori* review, assisting in the accuracy, completeness and accessibility of the studies (Moher et al., 2015).

Information sources and search strategy

A rigorous search of the literature was conducted in the following electronic databases: PsycInfo (APA); ProQuest (Physical Education Index); SportDiscus via EBSCO; Scopus (Elsevier); and Web of Science - Core Collection (Clarivate Analytics). The choice of these databases was based on their use of systematic reviews related to social support in the area of Sport Sciences (Bremer, 2012; Sheridan et al., 2014), in which a manual secondary search was performed in reference lists to source additional studies.

In each search engine, terms related to the study topic were input ("Influence" OR "Support" OR "Involvement") and were combined with population-related terms ("Athlete" OR "Parents" OR "Family" OR "Coach" OR "Peers" OR "Teammate") and research context (Sport), using the Boolean operator AND to combine terms related to topic, population and context ("Influence" OR "Support" OR "Involvement" AND "Athlete" OR "Parents" OR "Family" OR "Parent Coach" OR "Teammate" AND "Sport").

Eligibility criteria

The criteria governing the eligibility of the articles sourced followed the literature recommendations for such studies (Meline, 2006). We considered, for the purpose of analysis, original articles in English and from the period between 2001 and 2018 (21st century) that presented an abstract and a full text available online.

The eligibility assessment was carried out in a standardized and independent fashion by two researchers who were graduates in Physical Education, were attending the Human Movement Sciences Graduate Program and had with experience in the production of scientific research and systematic reviews. Disagreements were solved by consensus, with the assistance of a third investigator when a consensus could not be reached (Prat et al., 2019). Studies were included and excluded following the PRISMA PECOS criteria (Figure 1). After the searches had been performed in the databases, duplicate studies were eliminated. Finally, three steps were followed for selecting studies, based on the following eligibility criteria: reading of the title; reading of abstracts; and reading of the full texts. Eligibility for inclusion in the final studies was verified by calculating the degree of agreement or reproducibility between two data sets using Cohen's Kappa index (Cohen, 1960). A value greater than 0.87 was obtained, indicating a level of perfect agreement between evaluators (Anguera & Hernández-Mendo, 2014; Landis & Koch, 1977).

		Inclusion	Exclusion
P	*Participant*	Athletes (family, coaches and teammates)	Non-athletes
E	*Exposure*	Sports training and competition	School physical education: physical activity and physical exercise.
C	*Comparison*	Social Agents: family, coaches and teammates Support level: positive, indifferent and negative	--
O	*Outcome*	Athletes' perception of social support (influence, involvement) in sport	Perception of family, coaches and teammates
S	*Study*	Empirical Investigation (field studies – descriptive, transversal)	Experimental, theoretical and instrumental

Figure 1
Inclusion and exclusion criteria of the studies selected for the review.

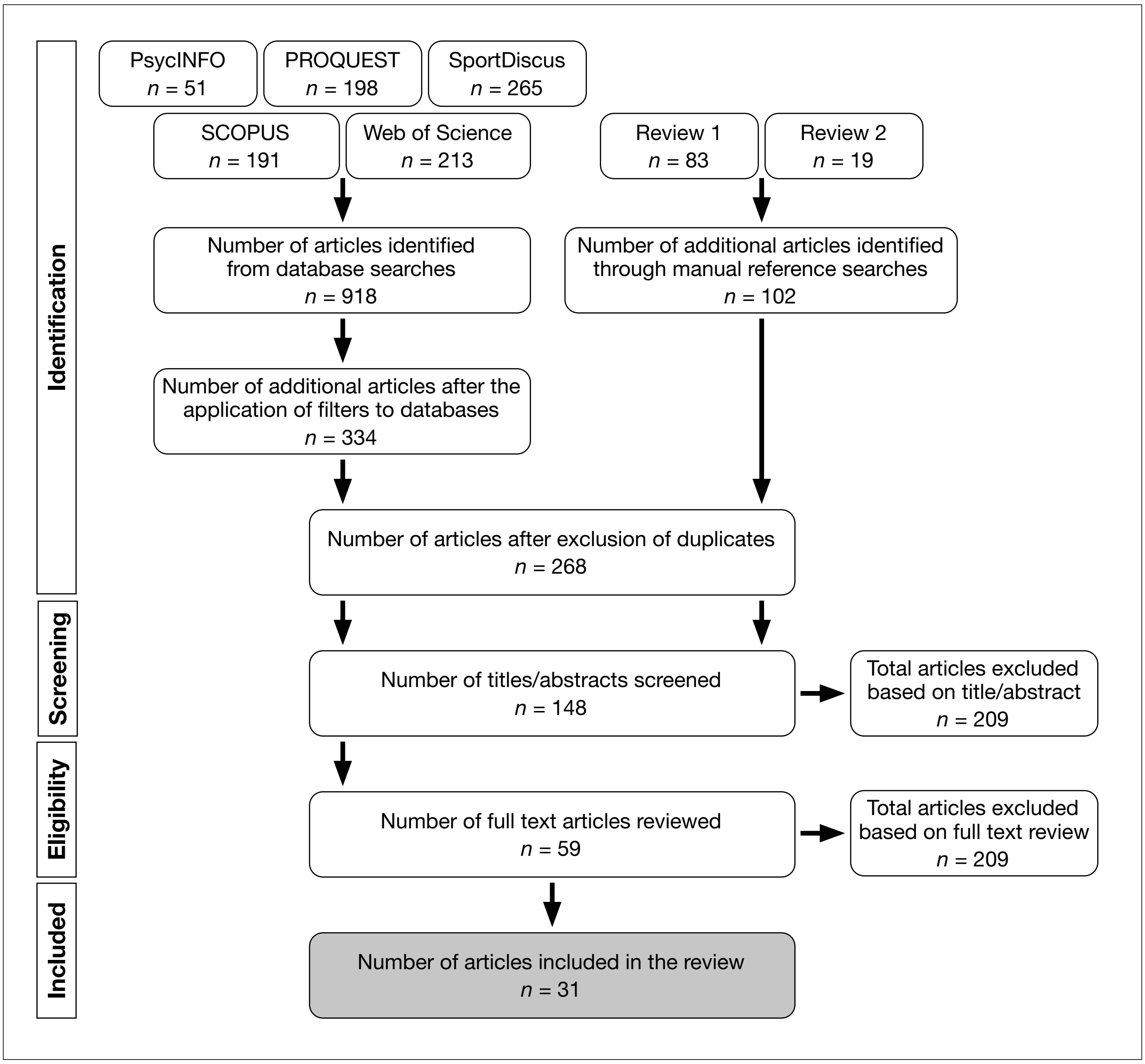

Figure 2
Modified PRISMA flow chart outlining records collected and final records eligible after screening process.

The search in the (primary and secondary) databases was performed in the first fortnight of November 2018 and yielded 1,020 records. 179 articles were excluded in the screening stage through the reading of the titles, because they failed to fulfil the following PECOS criteria: participant (9); exposure (4); outcome (132); study (3); exposure/outcome (8); participant/outcome (19); participant/study (2); outcome/study (2).

Following the reading of the abstracts 30 articles were ruled out on the strength of the following criteria: participant (8); outcome (7); study (4); participant/outcome (6); participant/exposure (5). Finally, in the eligibility stage, 28 articles that did not meet the outcome (27) and language (1) criteria were ruled out. A flow chart summarizing the study selection process is presented in Figure 2.

Evaluation of the methodological quality of the studies

Each one of the studies under review was independently appraised for quality by two researchers using the adapted checklist of the items included in the cross-sectional studies (STROBE - Elm et al., 2008). The checklist was originally comprised of 22 items, 17 of which were used in this study and are related to the title and abstract of the article (item 1), the introduction (items 2 and 3), the methods (items 4-8 and 10-12), the results (items 13-14 and 16) and the discussion sections (items 18-20).

The studies were classified according to the following cutoff points: A (>80% high); B (50% to 80% moderate); and C (<50% low). The cutoff points were obtained from the sum of the score applied to each item: 0 (does not answer); 1 (answers) (Olmos et al., 2008). Disagreements between the investigators were resolved by consensus. The methodological quality scores for all the studies included are presented in Table 1.

Data extraction and analysis

The studies extracted were organized and archived using Endnote (X7) software, while categorization and analysis were performed with the aid of the QSR NVivo PRO software (version 12). According to the information presented in the studies, the characteristics (year, study location, gender, stage of sport development - based on age - kind of sport; social agents investigated; type of research, instrument and software used) and study quality were quantitatively analysed using descriptive statistics (absolute frequency).

Results

The study findings were qualitatively analysed through the creation of analysis categories and subcategories, defined a *priori*, based on the conceptual framework, and a *posteriori*, based on the empirical data of the studies: social agents (family members, coaches and teammates); type of social support (emotional, informative, tangible); and level of social support (positive, indifferent, negative).

Characteristics of the studies

The characteristics of the 31 studies selected for this systematic review are presented in Table 1. Most of these research was published as of 2010 (21). In terms of study site, four were conducted in the United States of America and four in the UK.

The bulk of the research was conducted with athletes of both sexes (24), while only one was conducted with male athletes. With regard to the athletes' long-term development stage (Côté et al., 2003), 10 studies were conducted with athletes in the three stages (diversification, specialization, investment), and 14 studies included individual and team sport athletes.

The studies using a quantitative approach (16) collected data through questionnaires (16), while qualitative approach-based studies (14) employed semi-structured interviews (10), and only one research piece was conducted with both approaches. The SPSS (n = 4) and NVivo (n = 4) software applications were used most to assist in data analysis. There was also a predominance of studies that took into account the athletes' perception of the support provided by their families (13) (Table 1).

Risk of bias

Based on the guidelines used (Elm et al., 2008; Olmos et al., 2008), most studies (23) were classified as having a high methodological quality, and eight studies were classified as being moderate-quality. Overall, the risk of bias in the studies included was deemed relatively low.

Social agents, type and level of social support

The study results were organized around the influence of the main social agents investigated (family members, coaches, teammates), focusing on the type (emotional, informative, tangible) and the level of support (positive, indifferent, negative) perceived by the athletes.

Family support

The information included about the influence of family members was taken from 24 studies (Figure 3). Our analysis showed that according to the perception of the athletes investigated in the studies selected family member support was predominantly emotional.

Table 1
Summary of study characteristics.

Author (s)	Year	Study location	Gender	Stages of development	Modality	Type of research	Instruments	Software	Social influences	Study quality
Wyllerman et al.	2002	NS	M/F	I	Individual	Quantitative	Questionnaires	NS	F/C	B
Wuerth, Lee & Alfermann	2004	Germany	M/F	S/SP/I	Individual Collective	Quantitative	Questionnaires	NS	F	A
Wolfenden & Holt	2005	England	M/F	SP	Individual	Qualitative	Semi-structured interviews	NS	F/C	A
Jowett & Timson-Katchis	2005	Republic of Cyprus	F	I	Individual	Qualitative	Semi-structured interviews	NS	F/C	A
Ullrich-French & Smith	2006	USA	M/F	S/SP	Collective	Quantitative	Questionnaires	NS	F/T	A
Schinke et al.	2006	Canada	M/F	S/SP/I	Individual Collective	Qualitative	Semi-structured interviews	NS	F	B
McCarthy & Jones	2007	England	M/F	S	Individual Collective	Qualitative	Focus groups / semi-structured interviews	NS	F/C/T	A
Jowett	2008	England	F	S/SP/I	Individual	Qualitative	Semi-structured interviews	NS	F/C	A
Ullrich-French & Smith	2009	USA	M/F	S/SP	Collective	Quantitative	Questionnaires	NS	F/T	A
Keegan et al.	2009	NS	M/F	S	Individual Collective	Qualitative	Interviews - focus group	NVIVO	F/C/T	A
Keegan et al.	2010	NS	M/F	S/SP/I	Individual Collective	Qualitative	Focus groups / semi-structured interviews	NVIVO	F/C/T	A
Bhalla & Weiss	2010	Canada	F	SP/I	Individual Collective	Qualitative	Semi-structured interviews	NS	F	A
Fry & Gano-Overway	2010	NS	M/F	S/SP/I	Collective	Quantitative	Questionnaires	NS	C/T	A
Jowett & Cramer	2010	NS	M/F	SP/I	Individual	Quantitative	Questionnaires	NS	C	A
Lauer et al.	2010	NS	M/F	I	Individual	Qualitative	Semi-structured interviews	NS	F	A
Taylor & Bruner	2012	England	M	S/SP/I	Collective	Quantitative	Questionnaires	EQS	C	B

Note. Stages of development (defined based on Côté, Baker & Albernethy, 2003); S: Sampling (up to 12 years); SP: Specialization (13 to 15 years); I: Investment (over 16 years); M: Male; F: Female; NS: Not specified; F: Family; C: Coaches; T: Teammates; A: High quality, B: Moderate quality.

Table 1 (Continuation)
Summary of study characteristics.

Author (s)	Year	Study location	Gender	Stages of development	Modality	Type of research	Instruments	Software	Social influences	Study quality
Siekańska	2012	NS	M/F	I	Individual Collective	Quantitative	Questionnaires	NS	F	B
Dionigi, Fraser-Thomas & Logan	2012	Canada	M/F	I	Individual Collective	Qualitative	Semi-structured interviews	NS	F	A
Nunomura & Oliveira	2013	Brazil	M/F	SP/I	Individual	Qualitative	Semi-structured interviews	NS	F	B
Rottensteiner et al.	2013	Finland	M/F	SP/I	Collective	Quantitative	Questionnaires	SPSS	C	A
Atkins et al.	2013	USA	F	SP	Individual Col-lective	Quantitative	Questionnaires	EQS	F	A
Kubayi et al.	2014	South Africa	M/F	I	NS	Quantitative	Questionnaires	SPSS	F/T	B
Santi et al.	2014	NS	M/F	I	Individual	Quantitative	Questionnaires	SPSS/ AMOS	T/C	A
Amado et al.	2015	Spain	M/F	S/SP/I	Individual Col-lective	Quantitative	Questionnaires	SPSS	F	A
Marsh et al.	2015	USA	M/F	S/SP/I	Individual Col-lective	Quantitative - qualitative	Interviews / questionnaires	SPSS	F/C	B
Kang, Jeon & Kwon	2015	Korea	M/F	S/SP/I	NS	Quantitative	Questionnaires	PASW	F	A
Cranmer & Sollitto	2015	NS	M/F	I	Individual Col-lective	Quantitative	Questionnaires	NS	C	A
MacPherson, Kerr & Stirling	2016	NS	F	SP/I	Individual Collective	Qualitative	Semi-structured interviews / photo-elicitation	NS	T	A
Maniam	2017	Australia	M/F	I	Individual Col-lective	Qualitative	Semi-structured interviews	NVIVO	F	B
Danioni, Barni & Rosnati	2017	Italy	M/F	SP/I	Collective	Quantitative	Questionnaires	NS	F	A
Folle et al.	2018	Brazil	F	S/SP/I	Collective	Qualitative	Semi-structured interviews	NVIVO	F	A

Note. Stages of development (defined based on Côté, Baker & Albernethy, 2003); S: Sampling (up to 12 years); SP: Specialization (13 to 15 years); I: Investment (over 16 years); M: Male; F: Female; NS: Not specified; F: Family; C: Coaches; T: Teammates; A: High quality, B: Moderate quality.

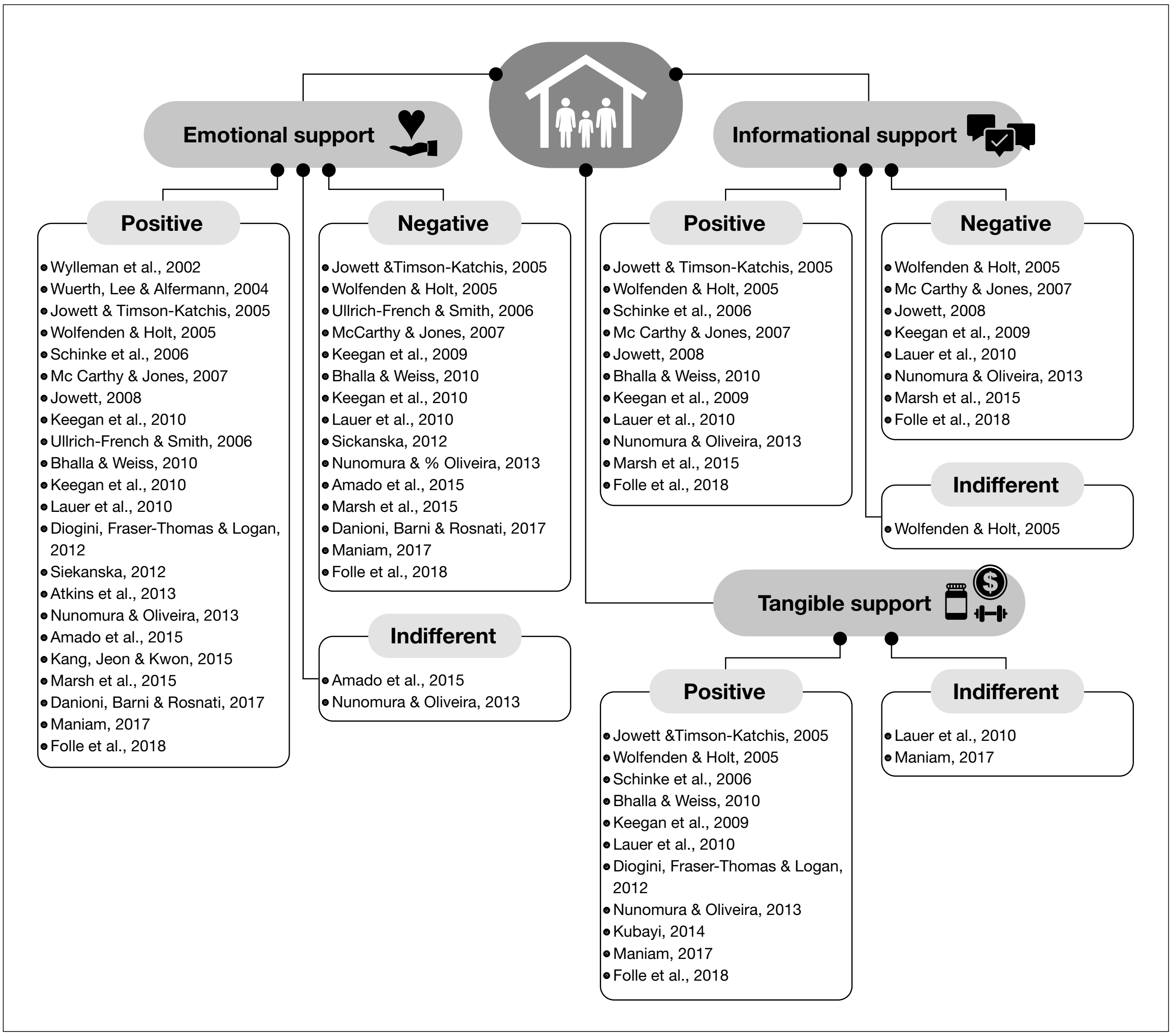

Figure 3
Studies that observed family support in sport.

The studies showed that the emotional support (23) provided by the family members was identified as a key factor in motivating athletes to do sport, showing that in general they were present (at training and competitions), provided encouragement and believed in the benefits of doing sport. However, in some of these studies, emotional support (16) from the family was also negatively rated by some athletes. In these cases, over-involvement (criticism, spontaneous expressions of disappointment, too much emphasis on winning, unrealistic expectations), rather than motivating, became a source of pressure and stress, particularly in competitive situations. In addition, two studies revealed that some athletes were indifferent to the type of emotional support provided by their family.

Our research findings showed that the family seeks to pass on information related to patterns of nutrition, rest, training and game performance through tips, advice and feedback. In general, this support was interpreted positively by the athletes investigated. On the other hand, the same instructional behaviours (7), when supported by deleterious aspects (negative feedback, disproportionate pressure), led the athletes to feel frustrated and demotivated in their involvement in the sport. In addition, one study emphasized that informative support by family members is perceived indifferently by athletes and has no influence on their doing sport (Wolfenden & Holt, 2005).

Positive perceptions of tangible support (11) showed that the availability of the family (the purchase of sports material and logistical support) for training and competitions was acknowledged by the athletes. In turn, disproportionate investment (2) led some athletes to feel pressured and dissatisfied with the support provided by their family.

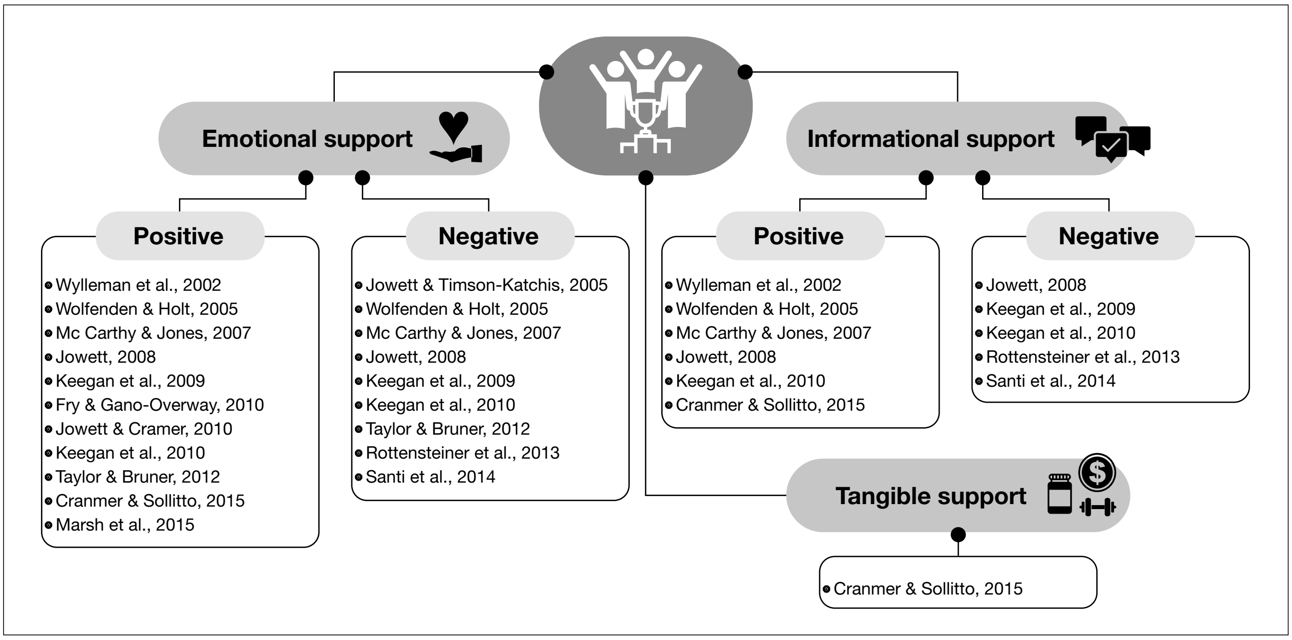

Figure 4
Studies that observed coach support in sport.

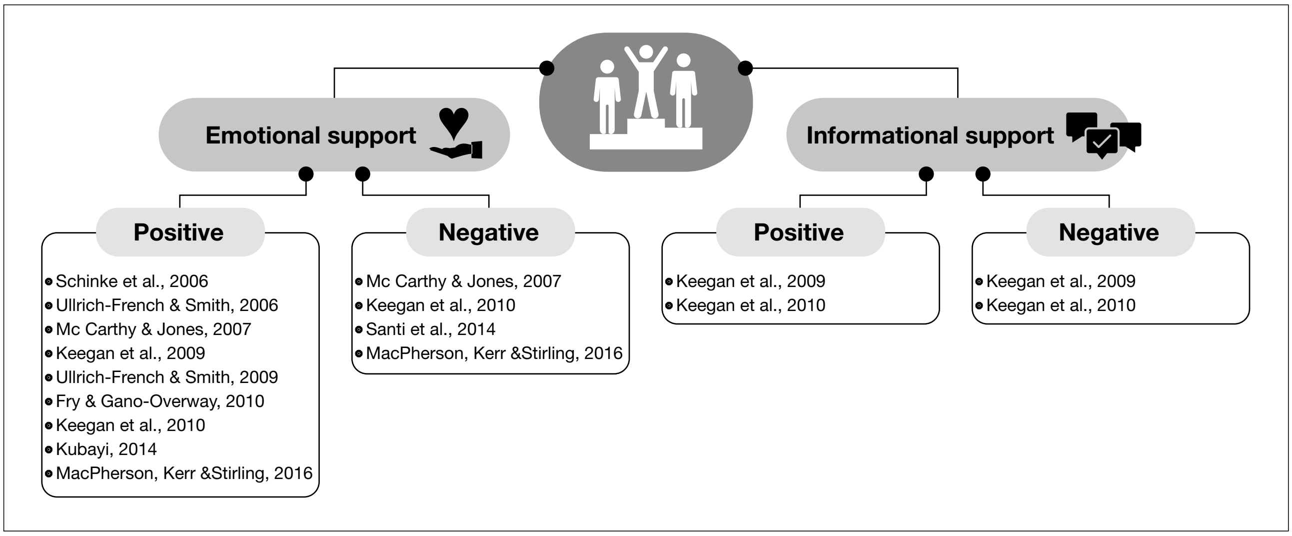

Figure 5
Studies that observed teammate support in sport.

Coach support

The information about the influence of the coaches was taken from the 14 studies shown in Figure 4. We observed, according to the perception of the athletes investigated, that the support provided to them by their coaches was mainly emotional and informative.

The results showed that positive emotional support from the coaches (motivational climate, trust and respect) directly affected the athletes' commitment to the sport (11). However, negative situations (demands, pressure, focus on results and sports performance) led athletes to feel pressured by the coach and dissatisfied with the sport (9). Perceptions related to informative support (feedback, orientation, tips), particularly for improving athletic performance, were highlighted by athletes as generating effective forms of motivation (5). However, some athletes pointed out that coach feedback was excessively critical and consequently had a negative influence on their confidence and development in their sport (5). Tangible support was poorly expressed in the athletes' perceptions (1).

Teammate support

The information analysed regarding the influence of teammates was taken from nine studies (Figure 5). In the athletes' perception, teammates provided mainly emotional support in the practice of sport.

A positive relationship with teammates (friendship, acceptance, encouragement) has been shown to contribute to the quality of athletes' experiences with the sport (8). However, negative attitudes (rejection, lack of support, ego) led athletes to develop competitiveness and rivalry with colleagues in their sport (4). Informative support (verbal comments and positive feedback) from colleagues was highlighted by athletes as a motivating factor in several situations (2). However, unfavourable aspects (criticism and negative feedback) emerged in competitiveness between athletes and prompted poorly adaptive sports-related consequences (2).

Discussion

The objective of this study was to analyse the scientific publications on the influence of social agents on sports to identify the types and levels of support provided to athletes by family members, coaches and teammates. Overall, this review pointed to an increase in the number of publications about the topic since 2010, conducted predominantly with athletes in the three stages of the sports practice, of both sexes and focusing on the analysis of social support by family members. The evidence suggests that family members provided the three types of support (emotional, informative and tangible) to athletes, while coaches mainly provided emotional and informative support and teammates emotional support.

The increasing number of publications about social influences on sport brings to light the current importance of the topic and researchers' concern with understanding the factors that interfere in the development of athletes, from the grass roots through to high-performance. This evidence indicates that research has sought to attain a multidimensional understanding of sport, particularly age- and gender-related variables, which can help practitioners to provide adequate support to athletes in the different stages of development and the development of both sexes (Sheridan et al., 2014).

One of the most relevant elements that emerged from this study was the range of research developed, with a specific focus on the family's influence on athletes' development, bridging a gap previously highlighted in the literature (Fredricks & Eccles, 2004). The athletes investigated in the different studies analysed found their main source of support in the family, regardless of their gender and stage in the sport. This means that throughout the athlete's trajectory, from initiation through to elite sport, and regardless of the type and level of support, family members bring a significant influence to bear upon athletes' careers, thus evincing the importance of the study of this agent, as has already been emphasised in the literature (Côté, 1999; Fraser-Thomas et al., 2005).

In this review, we hypothesised that family members provided greater emotional and tangible support to athletes. This hypothesis was partially supported, since the three types of support were perceived by the athletes. The evidence found in the selected research suggests that family members can mould athletes' experiences, which will be favourable if they show that they control emotions, respect, ethics and that they are committed to the athlete's goals. To this end, the family needs to understand that athletes will not be able to continue their involvement with the sport alone and that being empathic to the challenges they face in this setting will increase their chances of being successful in their career (Knight et al., 2018).

On the other hand, although positive levels of support are perceived by the athletes, a high number of studies have pointed to negative perceptions among athletes in relation to the family. In seeking to maximise benefits, especially for younger athletes, family members often engage in high levels of emotional, informative and tangible support to the detriment of the athletes' sporting experiences.

The results showed that negative family behaviours such as pressure, demands and overemphasis on victory and performance create unrealistic expectations and dissatisfaction with sports. Another potentially significant element was the allocation of the family's financial resources to athletes' sports activities. It transpires that family members who are heavily invested in young athletes' sports carees expect some kind of return on this investment.

However, this type of situation can lead the athlete to feel over-pressured, detracting from the pleasure of their sport and consequently reducing their commitment to it (Dunn et al., 2016, Latorre-Román et al., 2020). Therefore, even when the support is positive it can also be perceived as negative, depending on how it is perceived and experienced by the the athlete.

The information obtained from this review showed coaches to be complementary sources of support. The second hypothesis proposed was not verified, because even when informative support is provided, emotional support was the support perceived most by athletes in their relationship with the coach. The results of the studies showed emotional and informative support by the coach, mainly through motivation, feedback and counselling, can forge lasting relationships that may lead the athletes to prolong their involvement with the sport (Pérez-González et al., 2019).

In turn, the coach can also be a negative source of support, when the latter is accompanied by disproportionate pressure and negative feedback on athletes' performance, prompting a lack of balance and of affective bonds that would otherwise be conducive to a relationship grounded in mutual respect and trust. Coaches must understand their athletes, inside and outside the context of sport and be seen to take a real interest in their lives. This attitude can help them to address athletes' needs better and help them to develop realistic skills and pursue goals that may lead to a successful sports career (Nascimento Junior et al., 2020; Rottensteiner et al., 2013).

Tangible support from coaches was rarely perceived by athletes in the studies analysed. This type of support includes the recognition that the coach provides the athlete with benefits or services (rehabilitation, injury treatment, training and exercise schedules, sports equipment or financial aid) intended to assist the athlete in the sport (Holt & Dunn, 2004; Rees & Hardy, 2000). Perhaps, particularly in younger athletes, this kind of support is not perceived as coming directly from the coach and may give family members or even the club or sports centre such responsibilities, which may have reduced the recognition of these acts in the analysis of the support provided by the coaches.

The relationship with teammates has been shown to contribute to the quality of athletes' experiences, mainly through emotional support, according to the third hypothesis of this study. Although the sports literature has focused predominantly on how adult social agents, such as family members and coaches, can shape athletes' development (Marsh et al., 2015), there seems to be a growing recognition that interaction with teammates constitutes a source for generating positive results in sport (Macpherson et al., 2016).

The results of the studies suggest that quality of friendship and peer acceptance are closely related to motivation, companionship, and consequently to a greater commitment to the sport on the part of the athlete (Ullrich-French & Smith, 2006).

As sports practice advances, the role of teammates is being reformulated and assumes more and more importance, especially in the specialization and investment phases. Becasuse in these stages, perhaps the most complex for athletes, there is a transition from adolescence and a habitual shift in roles played by significant adults (Côté et al., 2016).

However, conflicts with teammates can lead athletes to give up the sport completely (Scott et al., 2019). The evidence obtained, albeit predominantly positive, is consistent with that of Sheridan et al. (2014) in indicating that negative emotional and informative support from teammates involving an ego climate, high competitiveness and pejorative feedback is strongly related to burnout in sports. This means that athletes' continuity in the sport will also depend on the quality of their relationship with their teammates, which will be fundamental in the taking of such a decision.

Comparing the evidence in this review to the existing literature, the athlete's sports experience is directly influenced by the type and level of support from social agents in the form of different values and beliefs (Defreese & Smith, 2014). In this research, the results of the studies analysed showed that the support of social agents is predominantly perceived as positive, in accordance with the fourth hypothesis of this study. Thus, even when negative support is provided, it is perceived less often than positive support, showing that family members, coaches and teammates fulfilled their role of sharing athletes' needs, providing emotional, informative and tangible support to assist them in sports activities.

From this perspective, in order to help athletes to develop and effectively protect them from undesirable situations, it would seem crucial to look more closely at how social agents influence athletes' development in sport. This requires not only the analysis of the available research information, but also the construction of new studies that achieve a better understanding of the psychological mechanisms in specific contexts of sports culture and provide a greater understanding of how certain types and levels of support can influence continuation or abandonment of a career in sport.

Conclusions

The results of this systematic review provided a clear indication of the breadth and complexity of the different types and levels of support provided to athletes by social agents. Family members were identified as the only providers of all three types of support, giving athletes emotional, informative and tangible support at all three levels (positive, indifferent, and negative). Coaches provided greater emotional and informative support, whereas teammates demonstrated greater emotional support, both positive and negative, according to the athletes' perception. Overall, it would appear that identifying specific roles and responsibilities to be provided by each social agent, as well as a knowledge of athletes' demands and sports goals, would be helpful in guiding the development of a successful athletic career.

Several practical proposals for family members, coaches and the other social agents involved in the context of sport who work with athletes emerged from this review. Family members, coaches and teammates have been shown to bring a positive influence to bear on several factors that affect the development of athletes in sport. Family members were the only providers of all three types of support, thus indicating the significant and ubiquitous role of the family, both positively and negatively. This discovery can help family members to revisit their attitudes and the types of support they provide to athletes to ensure that supportive relationships are favourable and positive. This information can go some way to understand what specific types of support can help to protect athletes from the harmful effects of specific types of stressful effects arising from their involvement in sport over time. Therefore, in order to help athletes to maintain their involvement in sport, the closest social agents need to be aware of the type and level of support they provide to athletes at different times in their career as athletes.

Limitations and future directions

This study makes important contributions on how athletes perceive the influences of social agents in sport, analysing the types and levels of support provided by family members, coaches and teammates. However, this study has several methodological limitations, to wit: the inclusion of studies published only in English (this may have influenced the characteristics of the sample and may have led reports that could be culturally significant to be omitted); the elimination of studies that did not meet some of the eligibility criteria (out-of-date studies - 2001-2018) and did not observe the athlete's perception as the focal point of the research, concentrating rather on the perception of parents, coaches and colleagues of their influence on athletes' activity; failing to consider other social agents (teachers, non-sports friends, businessmen, sports members), who may also have limited the outcomes of the review. In addition, the sample sizes and the competition levels of the investigated participants were not considered and nor were comparisons drawn between athletes based on age, gender, sport and country of origin, which might go some way to explaining the results, based on the characteristics of the samples. Future studies could use a cross section of their research to understand how an athlete's social support network can influence them before, during and after a sport season, which would allow researchers to examine the influences of social agent relationships over time. Including athletic populations from different cultures could help to test the generality and validity of existing knowledge. Moreover, including insights from multiple social relationships and exploring possible moderating effects in a research project may yield meaningful information and make valuable contributions to the existing literature.

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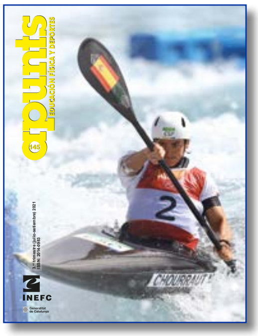

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External Load Demands and Positional Differences in Elite Futsal Using UWB Technology

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Maialen Chourraut (ESP) competing in Rio de Janeiro Olympic Games (2016), Whitewater Stadium. Women's Kayak (K1) Semi-final. REUTERS / Ivan Alvarado

Abstract

The physical conditioning demands on professional athletes in competition have been a subject of study over recent decades. The first objective of this study is to describe the external load demands on elite futsal players and then to verify whether there are differences among the specific playing positions. Fourteen professional first-division players in the Spanish National Futsal League were categorised into three groups according to their specific position on the court: stopper (S), flank (FL) and forward (FO). Goalkeepers were not included in this study. In the 2017-2018 season, a total of 15 official league matches were recorded using ultra wideband (UWB) technology with WIMU PRO devices The following variables were analysed: total distance travelled (TD); total distance travelled over 18 km·h^{-1} (TDHI: >18 km·h^{-1}); player load (PL); and number of high-intensity accelerations and decelerations (>/<2 m·s-^{2}). S, FL and FO did not present substantial differences in TD and PL, but they did in TDHI, where FL and S ran more metres at high intensity (FL = 274 ± 118 m; S = 249 ± 85 m) than FO (FO = 195 ± 60 m) and had more high-intensity accelerations (FL = 134 ± 46; S = 139 ± 40; FO = 118 ± 21) and high-intensity decelerations (FL = 128 ± 46; S = 131 ± 36; FO = 116 ± 23). The results of this study could support coaches, technicians and physical trainers in planning, designing and adjusting their players' training loads.

Keywords: competition; EPTS; external load; futsal; monitoring; team sport.

Introduction

Futsal is a team sport played on a court measuring 40 x 20 metres by two teams with five players (four players on the court and one goalkeeper per team). Any number of substitutions can be made without having to stop the clock, thus favouring a very high intensity throughout the match (Medina et al., 2001). Intermittent effort predominates in the matches, which consist of two 20-minute halves (Barbero, 2003) characterised by the repetition of short bursts of high-intensity effort and quick-paced play (Medina et al., 2001). with many changes in direction. Consequently, technical staff have to adjust their planning to the physical conditioning needs of competition by designing sessions intended to provoke positive and necessary adaptations of the players and the team by placing them in contexts as similar as possible to those they will subsequently encounter in competition (Casamichana et al., 2018).

The advent of GPS devices in sports competition and training has made it possible to monitor athletes' movements in both training and competition (Castellano & Casamichana, 2014). Numerous published articles have analysed the characteristics and positional differences of the competitive demands of different sports teams both outdoors (Dalen et al., 2016; Martín-García et al., 2018; Wehbe et al., 2014) and indoors, such as basketball (Fox et al., 2018; García et al., 2020; Puente et al., 2017; Svilar et al., 2018; Vázquez-Guerrero et al., 2018) and handball (Karcher and Buchheit, 2014). However, there are few studies on futsal, and most of them (Barbero, 2003; Barbero et al., 2014; Dogramaci et al., 2011; Hernández, 2001; Medina et al., 2001; Naser et al., 2017) refer to specific indicators, without taking the globality and complexity of the competitive demands into consideration, focusing rather on describing locomotor variables by means of video analysis (Barbero-Álvarez et al., 2008; Dogramaci et al., 2011; Hernández, 2001; Naser et al., 2017). Consequently, the main objectives of this study were: (I) to describe the physical conditioning demands on elite futsal players in official matches, and (II), to compare the differences in external load according to specific playing position.

Methodology

Participants

The external load of 14 professional players ($N=14$) (27.5±3 years; 174.9±6.8 cm; 72.2±5.3 kg) from the same first-division team in the Spanish National Futsal League, categorised into three groups according to their specific position on the court; stopper (S=5), flank (FL=7) and forward (FO=2), was recorded; goalkeepers were excluded from the study. At the time of the study, the players were doing between four and six training sessions and playing between one and three matches per week. The data analysed were obtained by monitoring the players on a daily basis, so that all their activities were regularly monitored throughout the season. The procedures used in this study observed the tenets of with the Declaration of Helsinki and were approved by the Scientific Research Ethics Committee (CEIC) of the Catalan Sports Council of the Government of Catalonia with number 17/CEICGC/2020. Before participating, the participants in the study were duly informed and provided their consent for their data to be used anonymously.

Design and procedure

The players were monitored over 15 official matches in the regular phase of the 1st division of the National Futsal League in the 2017-2018 season (11 victories, 3 ties and 1 defeat, ending the league in 2nd place). The matches were all played on the same court (matches played as the home team) and in similar environmental conditions. During the regular phase of the National Futsal League, each one of the 16 participating teams played a total of 30 matches in a regular league system with home and away matches, and the top 8 teams went on to the playoff as contenders for the league title.

The total length of the matches analysed was 80.0 ± 6.0 minutes (mean ± standard deviation), and the players' participation was 33.0±9.6 minutes, with FO being the players with the highest participation, with an average of 36.2±7.3 minutes, S with 32.8±12.4 minutes and FL with 32.2±9.8 minutes.

The players' external load was monitored using WIMU PRO™ inertial devices (Realtrack Systems S.L., Almería, Spain) with UWB technology. These devices have different sensors (accelerometers, gyroscopes, magnetometers, GPS and others). The frequency at which the accelerometer, gyroscope and magnetometer recorded data was 100 Hz, while the UWB data were recorded at a frequency of 18 Hz.

Between 8 and 12 minutes before the start of the match, and after a standard 24-minute warm-up, the devices were fitted on each one of the bibs worn by the players under their jerseys; the bibs were fitted and designed specifically to secure the devices to the upper back, just above the shoulder blades, without limiting trunk or arm mobility in any way. The players were monitored throughout all matches, although the external load was only quantified when the player was on the court (e.g., the data were not included when a player was substituted, during time-out or at halftime). At the end of every match, the data were downloaded and synchronised so that they could be analysed using the corresponding software (SPRO™, Realtrack Systems S.L., Almería, Spain).

Based on previous studies in basketball (García et al., 2020; Puente et al., 2017; Vázquez-Guerrero et al., 2018) analysing physical conditioning demands in competition, the following variables were analysed and presented in absolute and relative terms per minute: total distance travelled (TD) in m and total relative distance (TD_{REL}) in m·min-1; total distance travelled over 18 km·h-1 (TDHI: > 18 km·h^{-1}) in m and total relative distance travelled over 18 km·h^{-1} ($TDHI_{REL}$) in m·min-1; player load (PL) in arbitrary units (au) and relative player load (PL_{REL}) in au·min-1; number of high-intensity accelerations (> 2 m·s-²) and relative number of high-intensity accelerations in n·min-1; and number of high-intensity decelerations (> 2 m·s-²) and relative number of high-intensity decelerations in n·min-1. These variables were also chosen because they represent all the parameters used to monitor and quantify the daily external load by different sports and teams in the Sports Performance Area in the club to which all the players participating in the study belonged.

Data analysis

To analyse the differences in the means of the variables between playing positions, a general mixed linear model was built (PROC MIXED) using Statistical Analysis System (version 9.4 of SAS Studio - SAS Institute Inc., Cary, NC, USA). The random effects were player identity (to account for repeated measurements in the players), match identity (to account for the mean general differences between the matches) and the residual (to account for the differences between the players in the matches). Separate variances were estimated for each playing position, the random effect of the player and the residual, and these variances were combined to obtain standard deviations (SD) observed between players in each position. The three SDs were then averaged (via weightings of the degrees of freedom of the variances) to yield a general result of the player's SD in a typical match, and this SD was used to standardise the differences between the means of the playing positions. The playing positions were used as fixed effects (three levels). A Poisson regression was used to analyse the variables expressed as tallies. The magnitude thresholds for the fixed effects were < 0.2, 0.2, 0.6, 1.2, 2.0 and 4.0 for trivial, small, moderate, large, very large and extremely large, respectively (Hopkins et al., 2009).

The uncertainty in the estimates of the effects is presented as 90 % compatibility limits. The decisions based on the magnitudes of the effects were based on unilateral hypotheses of substantial magnitudes (Lakens et al., 2018). The p value to reject a hypothesis of a given magnitude was the t-distribution area of the statistic of the effect with values of that magnitude. The hypotheses of substantial decreases and increases were rejected if their respective p values were under .05. If a hypothesis was rejected, the p value for the other hypothesis was interpreted as evidence of that hypothesis, as the p value corresponds to the subsequent likelihood of the true effect size in a previous minimally informative Bayesian reference analysis (Hopkins and Batterham, 2019). The p value is reported qualitatively using the following scale: .25 – .75, possible; .75 – .95, probable; .95 – -.995, very probable; > .995, more probable (Hopkins et al., 2009). If none of the hypotheses was rejected, the effect size was regarded as unclear and is displayed without a probabilistic descriptor.

Results

Table 1 presents the mean values ± standard deviation of each one of the variables analysed for each specific playing position including the effect magnitude ± confidence intervals and the decision for the positional differences.

The objectives of this study were to describe physical conditioning demands on elite futsal players in official competition and to examine whether there were differences between specific playing positions. The results suggest the following: (1) the mean external load values per player per match were: TD = 3052 ± 804 m; TD_{REL} = 88.7 ± 15.3 m·min^{-1}; TDHI = 254 ± 101 m; $TDHI_{REL}$ = 7.5 ± 2.9 m·min^{-1}; PL = 57.2 ± 15.2 au; PL_{REL} = 1.7 ± 0.3 au·min^{-1}; high-intensity accelerations = 135 ± 41 *n*; relative high-intensity accelerations = 3.9 ± 1.0 n·min^{-1}; high-intensity decelerations = 129 ± 39 *n*; relative high-intensity decelerations = 3.8 ± 1.0 n·min^{-1}; (2) no substantial differences were found between S and FL for any of the external load variables analysed; (3) TD and TD_{REL}, PL and PL_{REL} do not seem to be dependent on playing position, with all three specific playing positions presenting similar values; and (4) substantial differences were observed between positions in variables related to intensity in both absolute values (TDHI, high-intensity accelerations and decelerations) and relative values ($TDHI_{REL}$, high-intensity relative accelerations and decelerations).

To our knowledge, this is the first study to conduct an analysis of external load demands in elite futsal official competition using UWB technology while also comparing

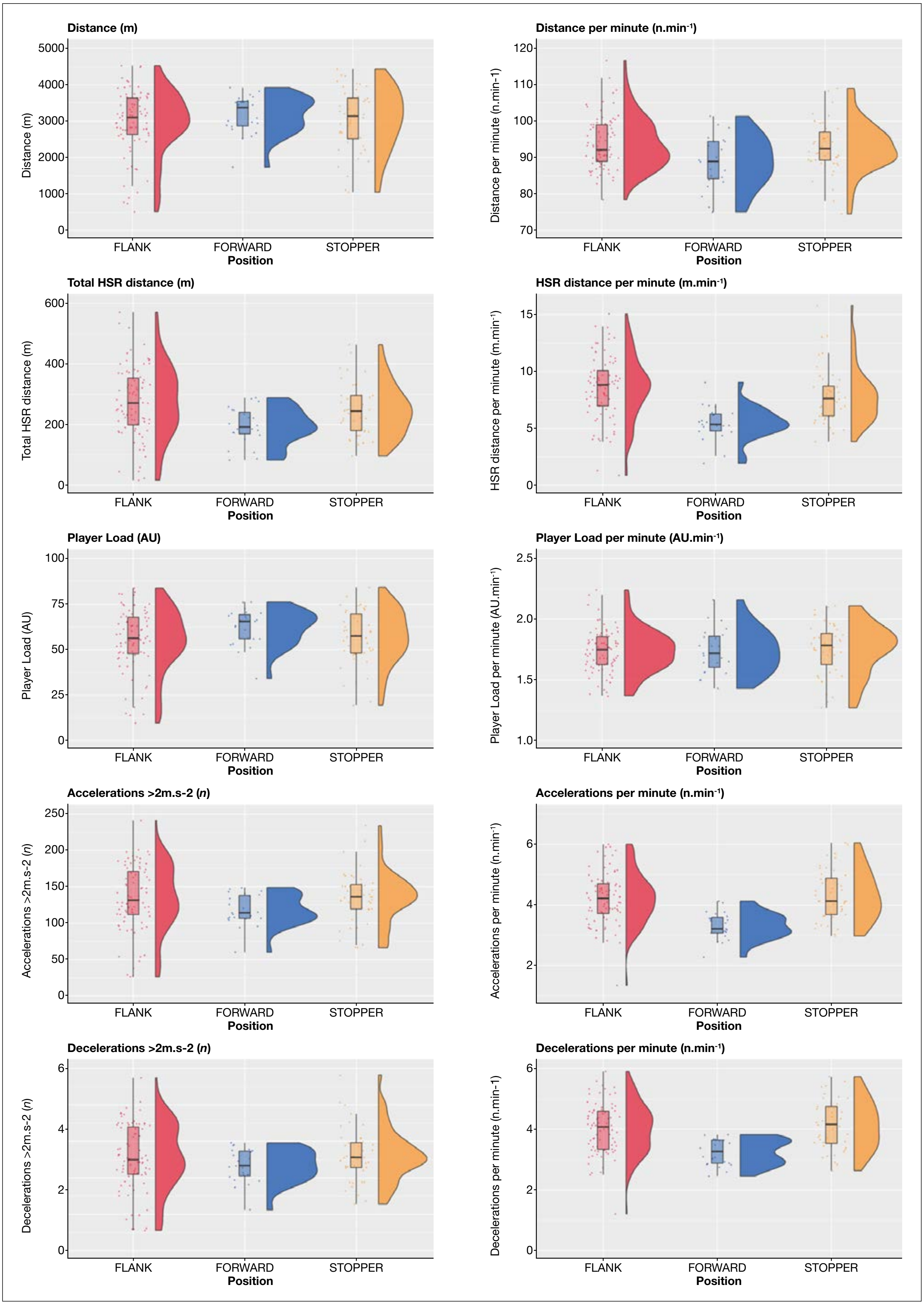

Figure 1
Box plot and violin plot and data distribution by variable in absolute and relative values.

Table 1
Mean values and standard deviations (SD) of the different variables analysed by position and differences between positions.

	Season average (Mean ± SD)			Positional differences (Effect size ± confidence intervals; decision)		
	Flank	Forward	Stopper	Flank-Forward	Flank-Stopper	Forward-Stopper
TD (m)	2961 ± 893	3184 ± 522	3034 ± 852	-0.32 ± 0.78; unclear	-0.03 ± 0.82; unclear	0.29 ± 0.89; unclear
TD_{REL} (m.min^{-1})	93 ± 10	89 ± 7	93 ± 7	0.42 ± 2.24; unclear	0.03 ± 0.40; unclear	-0.38 ± 1.93; unclear
TDHI (m)	274 ± 118	195 ± 60	249 ± 85	0.71 ± 0.70; moderate**	0.16 ± 0.70; unclear	-0.55 ± 0.31; small***
$TDHI_{REL}$ (m.min^{-1})	8.6 ± 2.8	5.4 ± 1.5	7.9 ± 2.4	1.12 ± 0.74; moderate***	0.16 ± 0.77; unclear	-0.95 ± 0.83; moderate**
PL (AU)	55 ± 17	62 ± 10	57 ± 15	-0.57 ± 0.70; small**	-0.11 ± 0.78; unclear	0.46 ± 0.70; unclear
PL_{REL} (AU.min^{-1})	1.7 ± 0.2	1.7 ± 0.2	1.8 ± 0.2	-0.18 ± 2.20; unclear	-0.08 ± 0.78; unclear	0.11 ± 1.62; unclear
HIA >2m.s^{-2} (*n*)	134 ± 46	118 ± 21	139 ± 40	0.25 ± 0.71; unclear	-0.21 ± 0.73; unclear	-0.46 ± 0.61; small**
HIA_{REL} >2m.s^{-2} (n.min^{-1})	4.2 ± 0.9	3.3 ± 0.4	4.3 ± 0.8	1.09 ± 0.71; moderate***	-0.23 ± 0.82; unclear	-1.32 ± 0.77; large***
HID >-2m.s^{-2} (*n*)	128 ± 46	116 ± 23	131 ± 36	0.18 ± 0.87; unclear	-0.19 ± 0.71; unclear	-0.36 ± 0.93; unclear
HID_{REL} >-2m.s^{-2} (n.min^{-1})	4.0 ± 0.8	3.2 ± 0.4	4.1 ± 0.8	1.03 ± 0.67; moderate***	-0.29 ± 0.92; unclear	-1.32 ± 0.80; large***

Note. TD: total distance (m); TD_{REL}: total relative distance (m·min^{-1}); TDHI: distance travelled at high intensity (> 18 km·h^{-1}) (m); $TDHI_{REL}$: relative distance travelled at high intensity (> 18 km·h^{-1}) (m·min^{-1}); PL: player load (AU); PL_{REL}: relative player load (AU·min^{-1}); HIA: high-intensity accelerations (> 2 m.s^{-2}) (*n*); HIA_{REL}: relative high-intensity accelerations (> 2 m.s^{-2}) (n·min^{-1}); HID = high-intensity decelerations (> -2 m.s^{-2}) (n); HID_{REL}: relative high-intensity decelerations (> -2 m.s^{-2}) (n·min^{-1}); **: probable; ***: very probable

the differences between the different positions on the playing court. Previous studies have described the TD travelled by futsal players during competition, such as the study by Dogramaci et al., (2011), which described how Australian players travelled a total distance of 4277±1030 m per match. These values are similar to those recorded on players of a futsal team in the Spanish Professional Futsal League, who ran an average of 4313±2139 m per match (Barbero-Álvarez et al., 2008). The recording methodology in both studies (both used video analysis technology) may account for the differences with the results found in our study (TD = 3052±804 m).

FO seem to be exposed to a lower total external load than their teammates, as is also the case in basketball (Vázquez-Guerrero et al., 2018). S and FL recorded higher high-intensity activity indexes than FO, made more accelerations and decelerations and travelled a greater distance at high intensity. These results might be explained by the anthropometric features and the physical and technical qualities of FO, and especially by the fact that FO generally play within the team's tactical system and the play model.

As described in other team sports (Varley and Aughey, 2013; Vázquez-Guerrero et al., 2018), identifying specific acceleration profiles may help coaches, technical staff and sports scientists to tailor exercises for each position with the goal of improving the athletes' level of physical conditioning.

Although physical conditioning demands have been generally expounded and described in outdoor team sports such as football (Martín-García et al., 2018) and rugby (Gabbett et al., 2012) using absolute values, the internal logic of futsal, with rules that make for a free, unlimited dynamic of substitutions, seems to require the use of relative load values as a more representative method to describe the competition load. In basketball, for example, the TD_{REL} per player fluctuates between 76.6 and 86.8 metres (Puente et al., 2017), in handball it varies between

87 and 101 metres (Barbero et al., 2014), while in futsal it ranges from 108 to 117.3 metres (Barbero-Álvarez et al., 2008), these latter values being higher than those recorded in our study ($TD_{REL} = 88.7 \pm 15.3$ m·min^{-1}). This decrease in the TD_{REL} may be related to the increase in the amount of time dedicated in recent years by teams to the 5c4 playing system (a system in which the goalkeeper is replaced by a field player, creating constant on-court numerical superiority).

Although the small sample size could be considered a limiting factor, it should be borne in mind that all the players participating in the study were on the same team, a common fact in studies based on professional teams. Consequently, given that the team's play model analysed may have conditioned the results to a certain extent, caution should be exercised when decisions based on them are taken. Another factor to consider is that in this study only external load values obtained via devices equipped with ultra wideband (UWB) technology were analysed. Including internal load variables (e.g., variables based on heart rate or on the subjective perception of effort) in future studies could herald a significant contribution to the process of monitoring competitive and training loads. Such future studies should also include a larger sample of participants, if possible from other teams in the same category, and should analyse more matches in order to confirm these results.

Conclusions

The findings of this study offer a new perspective of knowledge about physical conditioning demands in elite futsal, in the understanding that their description, based solely on speed-related locomotor variables, may not be sufficient to understand the complexity of competition and training.

In this context, the differences observed in the intensity variables between different specific playing positions should help coaches, physical trainers and other technical staff to design training tasks and sessions that fit each athlete's individual needs better and to plan the training process best suited to the demands of competition.

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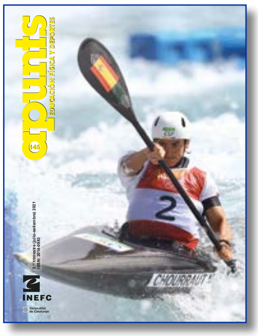

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A specific neuromuscular warm-up focusing on ankle sprain injuries in elite basketball

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Maialen Chourraut (ESP) competing in Rio de Janeiro Olympic Games (2016), Whitewater Stadium. Women's Kayak (K1) Semi-final. REUTERS / Ivan Alvarado

Abstract
A review of previous research was carried out to discover strategies to prevent ankle injuries in basketball. Studies about neuromuscular and proprioceptive exercises were investigated to ascertain the benefits and limitations. The main goal of this publication is to propose a weekly ankle-specific neuromuscular programme for an elite basketball team, including this ankle proposal during teams' pre-basketball training warm-up sessions.

Keywords: adjuvant training, injury prevention, neuromuscular training, optimizer training, proprioceptive training, team sports.

Introduction

Basketball is a sport with high physical demands, and both the aerobic and anaerobic energy systems are stressed during games (Stojanovic et al., 2018). Basketball mainly involves numerous explosive actions: accelerations and decelerations, changes of directions, high-speed running, jumping and landing (Ostojic, 2006; Scanlan, 2011, Vázquez-Guerrero, 2019a). Currently, the information about basketball intensity during practice is provided by positional and inertial systems (Sánchez Ballesta, 2019). For example, an elite player could cover ~73 m·min^{-1}, ~3 m·min^{-1} at high-speed running >18 km·h^{-1}, ~1.3 a.u. player load per minute, ~4 acceleration and deceleration actions >2 m/s-2 per minute, ~0.2 jumps >3Gs per minute and ~1.3 impact >8Gs per minute (Vázquez-Guerrero et al., 2019b).

The ankle joint is the most commonly injured area in athletes (Gabbe et al., 2004). Almost 80 % of athletes with an ankle sprain could sustain repetitive sprains and ~72 % could develop chronic instability (Lentell et al., 1990). Epidemiology of ankle joint injuries in sports is 11 %-17 % (Borowski et al., 2008; Pasanen et al., 2017; Starkey, 2000), although they do not result in a greater loss of time (Rodas, G. et al., 2019). Basketball players are five times more likely to sustain an ankle joint injury after a previous ankle injury, with a recurrence rate of 73 % (Plisky et al., 2006; Pope et al.,1998). Players may experience ankle injuries, suffering disability and residual symptoms such as weakness, a feeling of instability and pain (Yeung et al., 1994). It is therefore important to reduce the rate of ankle injury.

Players with less strength in the lower limbs and fewer neuromuscular and proprioception abilities are at greater risk of sustaining an ankle injury (Eils et al., 2010; Riva et al., 2016). Furthermore, basketball players with dorsiflexion mobility limitations present a high rate of patellofemoral injuries risk (Backman & Danielson, 2011).

Previous studies describe different strategies based on proprioceptive and neuromuscular exercises to reduce ankle injury incidence, but few studies have been performed during team pre-practice warm-up (Padua et al., 2019). Regarding previous data, the implementation of a preventive program is necessary to reduce a player's risk of initial and/or recurrent injury. Sensorimotor and neuromuscular training has proven its effectiveness in improving strength, stability, balance and postural control (Pau et al., 2012; Steib et al., 2016).

For these reasons, ankle injury prevention must be a focus in basketball with a view to preparing players to cope with training and match demands. It is important that coaches, strength and conditioning trainers, medical staff and players share the responsibility for designing, implementing and performing preventive exercises (Riva et al., 2016; Pasanen et al., 2017; Rodas et al., 2019; Caldemeyer et al., 2020); we therefore consider that a holistic approach should be taken in preventive programs to reduce the risk of injuries in addition to load control instead of the professional performing them independently.

The aim of this proposal is to adapt an ankle-specific neuromuscular strength program to an elite basketball team's weekly training, including it in basketball warm-up sessions.

Ankle-specific neuromuscular warm-up

Warm-up is defined as a preparatory activity phase performed by players to reduce injuries and enhance neuromuscular performance. Specific warm-up effects based mainly on ankle joint neuromuscular training programs have been poorly investigated in basketball. Previous investigations have analysed the risk of ankle injury in basketball (Starkey, 2000; Gabbe et al., 2004; Borowski et al., 2008; Pasanen et al., 2017), developing different strategies to prevent ankle injuries using proprioceptive exercises (Pau et al,, 2012; Eils et al., 2010; Riva et al., 2016; Owoeye et al., 2018) or neuromuscular exercises (Lentell et al., 1990; Pope et al., 1998; Steib et al., 2016; Owoeye et al., 2018; Caldemeyer et al., 2020). Further, actually no investigations have been realized about exercises proposal during the basketball warm up practice, as well as has not been shown the periodization during the week. Based on this information, the proposal consists of selecting 9 exercises that activate the foot and ankle muscles through the performance of functional movements. Players perform the exercises as a circuit in pairs as part of the team's neuromuscular warm-up before regular practice. We establish a holistic approach including the functional movements that players perform during the game. By way of progression, we recommend including perturbations (teammate unbalancing teammate) and simple decision-making.

This proposal focused on the ankle joint for performance is included during a basketball week schedule as a part of a regular team warm-up (Table 1).

Table 1
Typical competition week.

+1 MD	-2 MD	-1 MD	MD	-2 MD	-1 MD	MD
Recovery regeneration treat-ments	Technical basketball session	Recovery regeneration treatments	Shoot around practice	Recovery regeneration treatments	Recovery regeneration treatments	Shoot around practice
	Strength and conditioning workout					
	Ankle-specific neuromuscular warm-up	**Ankle-specific neuromuscular warm-up**	EUROLEAGUE GAME	Tactical basketball practice court	**Ankle-specific neuromuscular warm-up**	ACB GAME
	Tactical basketball session	Tactical basketball			Tactical basketball session	

Note. Shows a typical competition week. We include the ankle specific neuromuscular warm-up on Tuesday second session, Wednesday and Saturday as a part of the regular team warm-up.

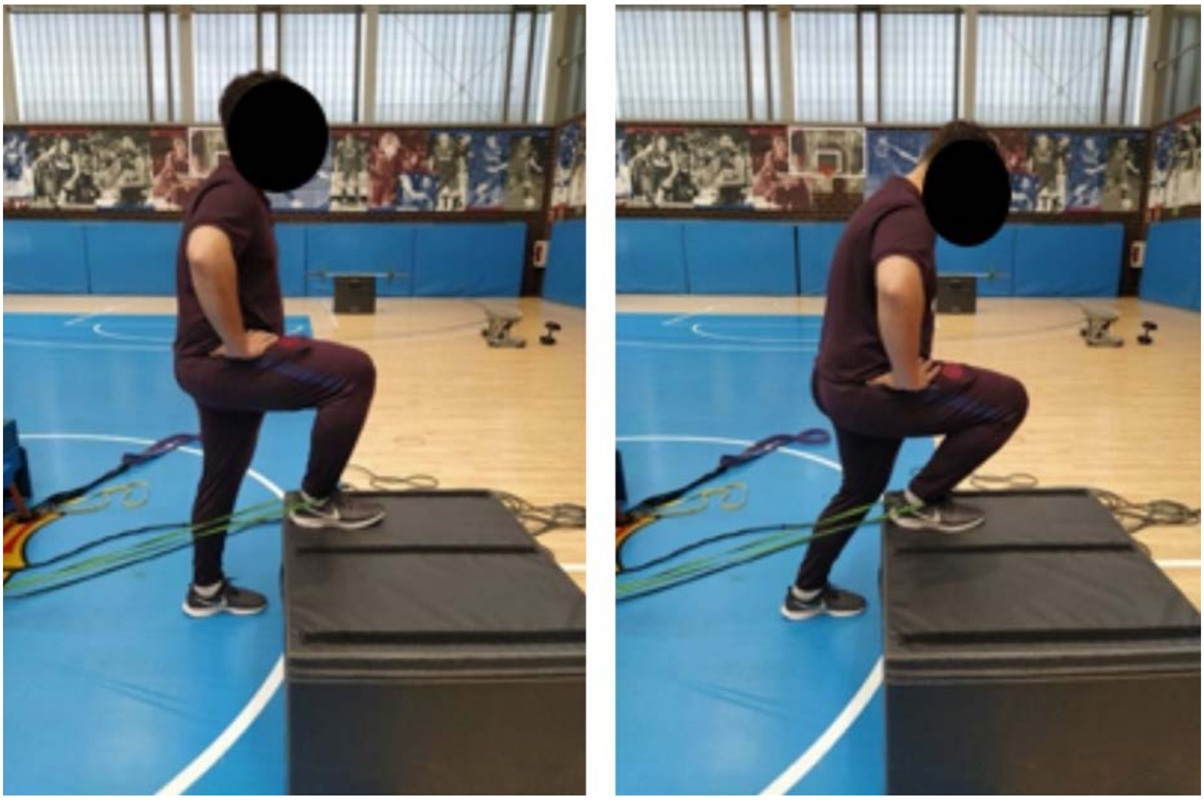

Figure 1
Ankle dorsiflexion mobility.

Ankle mobility (Figure 1)

From the standing position, the player places one foot on a box the top of which is level with the top third of the shinbone of the other leg. The distance of the elastic band is fixed in a position to generate sufficient tension to pull the ankle joint. This distance may vary depending on the player. The elastic band is placed at floor height and may be in line with the ankle or slightly displaced medially or laterally (up to 30º-45º). The elastic band should be placed just below the peroneal and tibial malleolus, the objective being to secure it to the neck of the astragalus. From this position, the player performs an active dorsiflexion, without moving their foot, and the heel must remain in contact with the ground at all times. Two sets of between 6 and 8 repetitions should be performed.

Working the peroneal muscles in CKC (Figure 2) and the tibialis posterior (Figure 3)

Place two platforms between 3 and 5 cm high on the floor. From the standing position, the player places each foot on one surface so that one half of the foot is in contact with the surface and the other half is not. From this position, the player touches the floor with the side of the foot that is free or not in contact with the surface (eccentric contraction). This is followed by a movement to return to the initial position (concentric contraction). This exercise focuses on the peroneus muscle (Figure 2). Same exercise idea is realized for posterior tibialis but placing the other half part of foot on platform and performing counter movement (Figure 3). Two sets of between 6 and 8 repetitions should be performed.

Figure 2
Peroneal neuromuscular work doing eversion movement.

Figure 3
Tibialis posterior neuromuscular work doing inversion movement.

Figure 4
Soleus doing plantar flexion neuromuscular work.

Figure 5
Single foot-active functional exercise. From static position on Pielaster is crossing up a light medicine ball doing a diagonal pattern.

Working plantar flexion in CKC with one-leg flexion of the knee on an Airex (Figure 4)

The player places one leg on an Airex. From this position, the player performs a (concentric) plantar flexion and an (eccentric) dorsiflexion in the full range of motion. The knee should be bent to between 30º and 70°. The player should use their hands to stabilize themselves if necessary. Two sets of between 6 and 8 repetitions should be performed.

Single-foot active functional exercise 1 (Figure 5

The player takes up position on one foot on an unstable platform with degrees of hip and knee flexion that allow them to attain a comfortable and stable position. From this position, the objective is to reach a static single-leg balance position on the Pielaster. Once this has been achieved, the next objective is to perform rotations with a soft medicine ball following diagonal patterns in different combinations. Two sets of between 6 and 8 repetitions should be performed. The repetitions will always be different, no more than 2-3 consecutive repetitions performing the same diagonal.

Single-foot active functional exercise 2 (Figure 6)

The player takes up position with one foot on a Pielaster-platform with degrees of ankle, knee and hip flexion that provide a comfortable position to perform an exercise while remaining stable. From this position, the first objective is to reach a static balance position. Once this has been achieved, the next goal will be to perform a hip and upper body flexion of up to 90 degrees with the other leg raised in extension. Players can place Mini Band-type elastic bands between their knees to increase exercise difficulty. Two sets of between 6 and 8 repetitions should be performed.

Figure 6
Single foot-active functional exercise. From static position on Pielaster and taking a elastic band with hands from in front, player is doing a single leg dead lift movement.

Lateral movement exercise (Figure 7)

From the standing position, the player attaches an elastic band to their hip and secures it to a stable surface that allows them to generate tension. The player should take up a position so that when they perform a lateral movement in one direction the elastic band will pull in the opposite direction. The exercise has to be performed taking two lateral steps at high speed. Two sets of between 6 and 8 repetitions should be performed. The repetitions should not always be performed in the same direction on one plane, but should be executed in different directions.

Footwork simulating competitive movement (Figure 8)

This exercise seeks to simulate "coordination ladders" by placing marks and using the lines of the field of play or court. Two players take up position, one on each side, ready to perform the same exercise identically, 4.9 m away from each other. From this position, they perform the footwork as quickly as possible and then run as speedily as possible to a 1.5 m-space marked out on the free-throw line. Each player should perform 2 sets of 3 repetitions. This work should always be done in pairs, it is a competitive exercise.

Figure 7
With an elastic band on hip from side, player is doing a side step.

Figure 8
Player does a simple footwork on a coordination stair and sprinting to arrive on a place before teammate.

Conclusions

This proposal provides an example of ankle joint neuromuscular exercises to be performed during pre-basketball practice warm-up. The main practical application for physiotherapists and strength conditioning professional is to show examples of exercises and how to organise this idea during a competitive week in an elite professional basketball schedule. Moreover, this idea would help medical staff to improve their injury prevention strategies.

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