Science & Sports (2019) 34, e45—e52

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ORIGINAL ARTICLE

Influence of fitness improvement on performance level in international elite young road-race motorcyclists

Influence de l'amélioration de la condition physique au niveau de la performance dans l'élite road-course jeunes motocyclistes internationaux

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Received 8 June 2016; accepted 27 August 2018
Available online 14 December 2018

KEYWORDS
Adolescents;
Motorsports;
Power;
Body composition

Summary
Objectives. — To describe physical fitness and performance profiles of elite young road-race motorcyclists and to evaluate the effects of four specific training stages on body composition and muscular fitness.
Equipments and methods. — Twenty-seven elite young road-race motorcyclists aged 15.6 ± 1.1 years, were evaluated on two different occasions, at the beginning and the end of the championship (14 weeks later). Body composition was measured using anthropometric techniques. Muscular fitness was assessed using the following tests: countermovement (CMJ) jump height, lumbar isometric strength, and handgrip strength. Sixteen of the participants were randomly selected as experimental group to perform 4 complementary training stages of 4 days each, while the rest of participants were used as control group.
Results. — Both groups improved significantly their physical fitness level, with average increments of about 3 cm in CMJ ($P = 0.003$) or 30 N in maximal handgrip strength ($P < 0.001$), among others. However, only the experimental group significantly improved competition results, evaluated with parameters such as place in the championship ($P = 0.040$), points ($P = 0.043$) and best

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https://doi.org/10.1016/j.scispo.2018.08.002

place attained during the championship. Fitness enhancement can be an effective strategy to improve performance. Our results indicate that riders following a conditioning program can achieve better results than those only performing motorcycling specific training.

MOTS CLÉS
Jeunes ;
Motocyclisme ;
Puissance musculaire ;
Composition corporelle

Résumé
Objectifs. — Décrire le profil de la condition physique et de la performance physique de jeunes pilotes de motocyclisme de niveau international et d'évaluer les effets des quatre périodes d'entraînement spécifique visant la composition corporelle et la remise en forme musculaire.
Matériel et méthodes. — Vingt-sept jeunes pilotes de motocyclisme âgés de 15,6 ± 1,1 ans, ont été évalués à deux reprises, au début et à la fin du championnat (14 semaines plus tard). La composition corporelle a été mesurée en utilisant des techniques anthropométriques. La force musculaire a été évaluée en utilisant les tests suivants : countermovement (CMJ), la force isométrique lombaire, et la dynamométrie manuelle. Seize participants ont été choisis au hasard comme groupe expérimental pour effectuer 4 périodes d'entraînement spécifique de 4 jours chacune, tandis que le reste des participants, en tant que groupe témoin, a réalisé l'entraînement habituel.
Résultats. — Les deux groupes ont amélioré de manière significative leur niveau de condition physique, avec une augmentation moyenne de 3 cm de CMJ ($p = 0{,}003$) ou 30 N dans la force maximale de dynamométrie manuelle ($p < 0{,}001$). Cependant, seul le groupe expérimental a significativement amélioré les résultats en compétition, ils ont été évalués avec des paramètres tels que le lieu du championnat ($p = 0{,}040$), les points ($p = 0{,}043$) et la meilleure position atteinte pendant le championnat. L'amélioration de la remise en forme peut être une stratégie efficace pour améliorer la performance. Nos résultats peuvent indiquer que les coureurs suivants un programme de conditionnement peuvent obtenir de meilleurs résultats que ceux effectuant seulement un entraînement de motocyclisme classique.

Introduction

Nowadays it is accepted that well planned training process is necessary to get the highest performance in any elite sport [1]. In road-race motorcycling, previous research has focused on the improvement of the motorcycle and the equipment developed by engineers and mechanics [2], although the athlete and his training regimen cannot be ignored if a better sport performance is to be achieved. So, elite road-race motorcycling must be based not only in the latest advances in materials or aerodynamics for the motorbike, but also in the knowledge of the rider and his physical fitness. Riding a motorbike needs the knowledge and management of the psychological and physical capacities, as well as how to use them in different situations. Limited research has studied physical and cognitive characteristics of motorsport participants [3] or riders' physiological variables during road-race competition [4—6].

Some authors suggest that physical training can improve fitness and so performance in road-race competitions [7,8]. Also the MotoGP 2010 world champion's father [9], underlined the importance of physical training as a key factor to perform adequately, and his son Jorge Lorenzo many times has expressed this idea in different interviews. However, to the best of our knowledge, there has been no study so far analyzing the effects of exercise interventions on motorcycling performance.

Previous researches (Sánchez-Muñoz et al., 2011) show that riders are small and light, with lower BMI, skinfold thickness, girth and breadth dimensions, and % BF than a reference group and other sports athletes of the same chronological age. The riders show high values of handgrip strength and lumbar isometric strength. Therefore, specific training should be oriented to these reference parameters.

To select and detect talented riders, DORNA (the company that manages road racing MotoGP championship) develops mono-mark championships like the formers called ''Solo-Moto Cup'', ''Ducados Cup'', or later ''Movistar Cup'' that nowadays is known as ''Red Bull MotoGP Rookies Cup''. This competition was also created to select the best pilots for the next categories, as this was the case years ago of the well-known MotoGP riders Dani Pedrosa, Jorge Lorenzo, Casey Stoner, Toni Elias, or more recently world champion Marc Márquez. In fact, four riders participating in the present study competed in the following season (2010) of the 125 cc world championship, scoring in some occasions between the 5th and 10th positions. Also a very important objective of the Red Bull MotoGP Rookies Cup is to teach the riders how to improve their technical and physical conditions, developing training stages to work specifically.

The purpose of this study was twofold:

- to describe physical fitness and performance profiles of elite young road-race motorcyclists, and;
- to evaluate the effects of four specific training stages during the competitive season on body composition and muscular fitness.

We hypothesize that an increase in the motorcyclist's fitness level can result in improved competition performance.

Methods

Participants

Twenty-seven elite young male road-race motorcyclists (mean age 15.6 ± 1.1 years) from 15 countries participated in the Red Bull MotoGP Rookies Cup 2009 (May—August), a competition open to young road-race motorcyclists from all over the world that constitutes the most important step to reach the Grand Prix motorcycle racing. To be included in the competition, a rigorous selection process was done by DORNA, the company holding exclusive commercial and television rights for the FIM Road Racing World Championship Grand Prix (MotoGP™). From a total of more than 1000 athletes from 60 countries, only 27 riders were finally selected and all included in this study. The process of selection of subjects is based on a worldwide program developed by DORNA, that selects the best riders from the different countries of the world that celebrate an official championship for these categories, and based on the riders' previous performance in these national races but not based on any specific physical fitness test.

Although at the beginning of the study 14 participants were randomly assigned to the control group (CG) and 13 to the experimental group (EG), 2 participants of the EG could not attend the intervention so they were finally assigned to the CG. So, in the end, 16 of the participants were part of the control group (CG) and the rest (11) served as the experimental group (EG). Riders' motorcycling experience at elite level was on average higher to 3.5 years. All subjects received information about the characteristics, procedures and objectives of the study. Written informed consents were obtained from the participants and from people in charge of the program at the beginning the study. For those riders who were underage, the written consent of their parents was obtained. The study was approved by the Ethics Committee of the University of Granada (Table 1).

Design

A randomized, two-group (Experimental -EG- and Control -CG-) pre- and post-test design was used to evaluate the effects on body composition, lower-body muscular power, hand grip strength, and lumbar isometric strength, after the implementation of a program consisting in four specific training stages through the competitive season and between the eight official races. First and second races took place during consecutive days on the same track as well as seventh and eighth. In between, four stages were performed separated each 21 days approx imately. Both groups executed a battery of tests for the evaluation of their physical fitness at the beginning and at the end of the Red Bull MotoGP Rookies Cup 2009. In addition, data related to the single competitions (1st to 8th) and to the whole championship were also collected.

Training

The specific training program developed in the four stages (4 days each) by EG included aerobic and strength-conditioning activities, CORE exercises, stretching and also motocross specific training and speed training on track (Table 2).

Flexibility: whole-body dynamic stretching exercises at main joints. Resistance training: major muscle groups (squat, bench press, pull up, press shoulder, leg curl, formearms), 3 sets of 10 repetitions at 60% of 1 repetition maximum (1RM), 3 minutes rest between sets. CORE: isometric and dynamic exercises on floor with unstable materials (planck, hip dip, crunch, twist crunch, lumbar quadruped), 3 sets per exercise. Stretching: static stretching of major muscle groups holding the position for 20—25 seconds, 2 sets per exercise.

The EG followed the training program, while motorcyclists in the CG continued with the specific motorcycling training program that both EG and CG performed immediately before each competition.

Measures

All participants were assessed on the same day and the tests were performed in the same order by the same research team. For fitness measurement, the riders were verbally encouraged to give their maximal effort.

Body composition

Weight was measured to the nearest 0.1 kg using a portable scale (model 707, Seca Corporation, Columbia, Maryland),

Table 1 Characteristics of the study participants (mean ± sd).

	Experimental Group (n = 16)	Control Group (n = 11)	Total (n = 27)	P-value[a]
Age, (years)	15.5 ± 1.3	15.2 ± 0.9	15.6 ± 1.1	ns
Weight, (kg)	52.3 ± 5.7	54.5 ± 8.4	53.2 ± 6.9	ns
Height, (cm)	166.2 ± 6.5	166.5 ± 7.5	166.3 ± 6.8	ns
Motorcycling experience, (years)	3.7 ± 2.6	3.6 ± 2.7	3.6 ± 2.8	ns

Ns = non significant.
[a] One-way ANOVA.

Table 2 Training distribution in the stages.

	Day 1	Day 2	Day 3	Day 4
Morning	Warm up	Motocross 2 h 30′ (30′ warm up; 4 × 15′: rec 20′; 2 × 30′)	Warm up	Cycling 2 h at 60—70% HRR
	Flexibility 20′		Running 40′ at 60—80% HRR	Stretching
	Resistance training, CORE exercises		Flexibility 20′	Theoretical session
	Stretching		Resistance training, CORE exercises	
	Cycling 1 h 30′ at 60—70% HRR		Stretching	
	Stretching			
Afternoon	Road-race motorcycling, specific technical training	Stretching 30′	Road-race motorcycling, specific technical training	
	Theoretical session	Theoretical session	Theoretical session	

HRR: Heart rate reserve.

and height was measured to the nearest 0.1 cm using a stadiometer (GPM, Seritex, Inc., Carlstadt, New Jersey). Skinfolds were obtained using a Holtain skinfold caliper (Holtain Ltd, Crymych, UK) and recorded to the nearest 0.2 mm, and girths were measured using a flexible anthropometric steel tape (Holtain Ltd, Crymych, UK) to the nearest 0.1 cm. Skinfolds measures were taken according to the standards of the International Society for Advancement of Kinanthropometry -ISAK- [10] at eight sites (biceps, triceps, subscapular, suprailiac, supraspinal, abdominal, thigh, and medial calf) three times and the mean of three measurements was used in the analyses. Body mass index was calculated as weight divided by height squared (kg/m^2). The regression equation of Durnin and Womersley [11] was used to estimate body density, and body fat percentage (%BF) was determined by the Siri's equation [12]. Percentage of muscle mass was determined using the method of Lee et al. [13]. All anthropometrics measurements were conducted by the same Level 2 ISAK anthropometrist.

Lower-body muscular power

An infrared platform Ergo Jump Plus-Bosco System (Byomedic, S.C.P., Barcelona, Spain) was used to assess lower-body muscular power (21). Each rider completed 3 maximal countermovement jumps (CMJs) with 3 minutes rest allowed between trials, recording the highest value. All CMJs were completed keeping the hands on the iliac crest to avoid the influence of the upper limbs on jump performance, and the starting position was standing straight. Then subjects flexed their knees to the squat position (90°) and performed a maximal vertical jump. Measured height was expressed in centimeters and was converted to power (W) using the equation by González-Badillo and Gorostiaga [2]. Our research group has shown that CMJ presents adequate levels of test-retest reliability [14] and criterion-related validity [15] in adolescents of similar age to these motorcyclists.

Hand Grip Strength

A Digimax electronic dynamometer (Mechatronic GmbH, Darmstadt, Germany) was used to determine maximal isometric handgrip strength in both right and left hands, and to determine sustained maximal isometric handgrip strength. The dynamometer was adjusted for each subject's hand size and the riders were kept in the standing position with the arms parallel to the ground and with the elbow joint maintained at 90° flexion. The subjects were instructed to perform two different tests:

- a maximal isometric contraction (each subject was allowed three trials with one-minute rest between trials, and the highest value was recorded), and;
- a sustained handgrip strength test consisting in ten maximal effort isometric contractions of 10 seconds with 10 seconds rest between maximal efforts.

The fatigue index measured was calculated to evaluate the loss of strength from the first repetition to the last one in this test.

Lumbar Isometric Strength

A lumbar extension dynamometer (Takei Kiki Kogyo, Tokyo, Japan) was used to determine lumbar isometric strength. The rider stood on the platform with the knees extended and the trunk flexed to an angle of 150°. Holding the bar with a pronated grip, the subject pulled it slowly but vigorously, extending the lower back. The best score of three trials with one-minute recovery between each was recorded and used in the analyses. The values obtained by the Takei were converted from kg to N.

Performance in competitions

In the Red Bull MotoGP Rookies Cup, all riders compete with a racing bike of equal characteristics: 125 cc engine, 45 horsepower at 13,000 rpm, bike plus rider = 136 kg. Data in each competition was recorded in terms of time of the fastest lap for the race start position, the fastest lap during

competition, or place in competition; also at the end of the championship the final position in the championship, points in the championship, and the best place in the championship were recorded. All this information was provided by the organization and was taken by means of official timing of the championship which is the same used in MotoGP events.

Statistical analysis

Standard statistical methods were used to calculate the means and standard deviation (sd). Variables were graphically inspected for normality. One-way analysis of the variance (ANOVA) was used to compare descriptive variables in EG and CG at baseline (pre-test). ANOVA for repeated measures was used to explore the effect of the training program in each group (pre vs. post and the interaction pre-post * group) regarding body composition and physical fitness. Race performance variables were analyzed using nonparametric tests (for related or independent samples according to the case) given their non-normal distribution. The alpha level of significance was set at $P < 0.05$ for all statistical procedures. All statistical analyses were carried out with the SPSS statistical package (version 15.0; SPSS, Inc, Chicago, Illinois, USA).

Results

The results of the initial and final tests of the studied motorcyclists are presented in Table 3 (race performance scores) and Table 4 (body composition and fitness level). Initially, no statistical differences were found for any variable at the beginning of the study (pre-test) between EG and CG. From pre-test to post-test, both CG and EG increased body weight ($P = 0.003$), BMI ($P = 0.014$), CMJ height ($P = 0.003$) and power ($P < 0.001$), maximal isometric strength for right hand ($P < 0.001$), mean hand grip strength in a sustained maximal isometric effort ($P < 0.001$), and lumbar isometric strength ($P < 0.001$), with no differences between groups.

Significant differences were found in CG for the starting position between pre- and post-test ($P = 0.014$) towards a decreased performance, while EG improved significantly in the starting position ($P = 0.021$). Comparing both groups in the post-test, significant differences were found in the place in the championship ($P = 0.040$), in the points in the championship ($P = 0.043$), and also in the best place attained during the championship ($P = 0.012$).

Discussion

This study aimed at describing physical fitness and performance profiles of elite young road-race motorcyclists, and evaluating the effects of four specific training stages during the competitive season on body composition and muscular fitness. Physical training has been shown as a very important factor in motorsports [16] and as a key factor to improve performance in road-race motorcycling competitions in adults [7—9]. MotoGP motorcyclists many times express the necessity of training physically hard to control the bike especially in the highest categories (Moto2 and MotoGP). Following this reasoning, a four stage training plan was designed to

Table 3 Pre- and post-test values for body composition and physical fitness in experimental and control groups (mean ± sd).

	Experimental Group ($n = 16$)		Control Group ($n = 11$)		*P*-value[a]	
	Pre-test	Post-test	Pre-test	Post-test	Pre-post	Pre-post[b] group
Weight (kg)	52.3 ± 5.7	53.8 ± 5.7	54.5 ± 8.4	55.7 ± 8.5	0.003	ns
BMI (kg/m²)	18.9 ± 1.3	19.3 ± 1.1	19.6 ± 2.0	19.9 ± 1.9	0.014	ns
Body fat (%)	11.8 ± 2.3	12.3 ± 3.0	13.7 ± 3.5	14.1 ± 4.0	ns	ns
Muscle mass (%)	49.5 ± 3.0	48.4 ± 3.5	47.3 ± 3.1	47.3 ± 2.5	ns	ns
CMJ Height (cm)	31.8 ± 3.9	34.9 ± 5.3	32.2 ± 5.7	34.6 ± 5.0	0.003	ns
CMJ Power (W)	1290.1 ± 172.4	1381.4 ± 209.1	1349.0 ± 286.01	1425.5 ± 272.2	<0.001	ns
HG strength (maximal)						
Right hand (N)	372.5 ± 65.0	399.5 ± 62.1	371.6 ± 94.1	404.9 ± 92.6	<0.001	ns
Left hand (N)	365.7 ± 67.7	377.1 ± 64.5	365.2 ± 82.6	360.7 ± 94.8	ns	ns
HG strength (sustained)						
Mean HG strength (N)	248.8 ± 47.1	303.7 ± 45.8	264.0 ± 51.2	303.7 ± 63.2	<0.001	ns
Fatigue index (%)	27.5 ± 17.1	21.0 ± 10.5	30.4 ± 7.6	34.6 ± 5.0	ns	ns
Lumbar isometric strength (N)	1009.5 ± 158.4	1205.0 ± 222.4	982.9 ± 192.3	1150.0 ± 130.9	<0.001	ns

BMI: body mass index; CMJ: countermovement jump; HG: hand grip; ns = non significant.
[a] ANOVA for repeated measures. Pre-post: within subjects.
[b] Pre-post group: between subjects.

Table 4 Race performance scores for experimental and control groups (mean ± sd).

	Experimental Group ($n = 16$)	Control Group ($n = 11$)	*P*-value
Starting position pre-test	12.5 ± 7.4	15.1 ± 8.2	ns
Starting position post-test	11.8 ± 7.5	17.2 ± 7.8	0.084[a]
Place in pre-test competition	9.1 ± 5.9	13.7 ± 4.9	ns
Place in post-test competition	9.3 ± 6.0	14.2 ± 6.3	0.074[a]
Final place in the championship	11.4 ± 7.5	17.7 ± 7.3	0.040*
Points in the championship	53.9 ± 44.0	23.5 ± 30.2	0.043*
Best place during the championship	5.2 ± 3.9	9.3 ± 3.8	0.012*

ns: non significant. *$P < 0.05$.
[a] Trends of significance.

improve young riders' physical condition as well as technical skills.

Our results indicate that the four stage training plan has been shown effective as EG improved performance in competition at the time trends of significance that could be of practical relevance were found in physical fitness. Although both groups showed improvements in the majority of the measured variables, EG presented higher gains related to physical fitness and, more clearly, the results in competition. However, different aspects have to be considered to better interpret the results obtained. On the one hand, no statistical differences were observed between EG and CG in any fitness parameter measured (neither in the pre-test nor in the post-test), which shows that there was no cause-effect relationship between the stages and improvements of the EG. This could be due to the short time working and the non-specific program followed on the training stages. On the other hand, EG group was able to achieve greater improvements in physical fitness parameters in the pre-test compared to the post-test, while the CG did not. Anyway, statistically significant differences were found between EG and CG for the performance variables in the competition. Results suggest that subjects who participated in the working program designed by DORNA, although they did not increase their physical performance significantly, they did improve their performance in competition.

According to anthropometric characteristics, no significant differences were found for any variable between EG and CG groups. At the end of the competitive season, curiously, both groups increased weight. This change seems to be not related to maturation, as % body fat increased and % muscle mass decreased in the second evaluation (although not reaching statistical significance). The observed values are comparable to those reported by our research group among elite junior tennis players [1], who showed higher body fat percentage and less muscle mass (between 11.8 and 14.1% ± 2.5 vs. 15.8% ± 3.6, for body fat and between 47.3 and 49.5% vs. 46.7%, for motorcyclists and tennis players respectively). Taking into account that EG showed the best sport performance, it seems that once an appropriate fitness level is reached small changes in body composition do not alter overall performance in this sport, in contrast to other sports such as running, road cycling or triathlon. Elite young road-race motorcyclists are small and light compared to other athletes of the same age, for example the tennis players previously cited, who were taller (176.8 ± 6.4 cm vs. 166.3 ± 6.8 cm), and heavier (69.9 ± 6.8 kg vs. 53.2 ± 6.9 kg), or compared to a reference population of the same age who were on average 170.9 ± 8.6 cm height and 63.8 ± 12.9 kg weight [17].

Although EG and CG groups increased weight, both improved slightly vertical jump values in the CMJ test although just EG did it significantly (3.1 and 2.4 cm, which corresponds to a gain of 9.8 and 7.5% respectively for EG and CG). In relation to weight, also CMJ power was increased (91 W and 75 W, respectively for EG and CG). Motorcyclists' jump height was between 31.8 and 34.9 cm, which is a similar performance as that achieved by junior soccer players [18] that performed between 33.8 and 36.3 cm. Other studies show higher values [19] between 41.4 and 43.2 cm for elite young soccer players. So, as motorcyclists do not need to transport their own body mass as soccer players, tennis players or runners do, we can consider this performance as good and very important for motorsports as suggested by previous authors [3].

Handgrip strength has been suggested as a very important predictor variable to control the motorbike [6]. These authors found that motocross riders showed significantly higher strength in the left hand compared to the right, may be due to the more frequent use of the clutch in this motorcycling modality. In our study the right hand was significantly stronger in the maximal isometric strength than the left hand, may be because the front brake is more used during competition than the clutch especially in the marked braking phases of the circuits. In fact, significant differences were observed between pre- and post-test in both groups that increased the values in 7.2 and 9% EG and CG respectively. No differences were found between groups. For the mean maximal handgrip strength, both groups improved the values in 54.9 and 39.78 N (22.1 and 15.1%) for EG and CG respectively. The fatigue index in this test was reduced 22.8% for EG and 9.2% for CG, which is very important because the maintenance of the hand strength is crucial to control the bike during the complete race. The EG took a clear advantage in this variable compared to the CG. Comparing the values observed in the subjects of this study and others, off-road motorcyclists (23–32 years) showed 128.4 N and 138.3 N more for right and left hands [6], and 95.9 N and 32.3 N more for top elite international

male motocross riders (28.3 ± 7.9 years). We believe that age can be the main factor affecting these differences.

No statistical differences between groups were found for lumbar isometric strength values, but in the post-test significant improvements were observed for both groups (19.4 and 17.0% for EG and CG). Lumbar isometric strength may be important for the pilot because of the body position when riding the motorcycle, mainly because of the constant body changes during the competition to move the bike right and left depending on the curves of the circuit. These muscles are necessary to be trained specifically to avoid injuries and perform adequately [20,21].

Analyzing specific performance in the circuit and competitions, no significant differences were found in the pre-test between EG and CG. After the treatment significant differences were observed between groups for the place in the championship, points in the championship, and also for the best place attained during the championship. This clearly shows that EG improved more than CG in the specific performance in the circuit. The starting position can be taken into account as a solid measure of rider's ability to ride fast as it is performed alone and as many times as necessary, and in the pre-test no significant differences were observed for starting position neither for the place in that competition. However, trends of significance were observed for these variables in the post-test, so it can be argued that EG became better than CG.

In conclusion, this study presents a unique view of an under researched sporting population never shown before, and it analyzes the performance before and after the competitive season. Also descriptive values are provided for body composition, physical fitness, and specific performance of elite young road-race motorcyclists. This study suggests that the specific training program presented by Red Bull MotoGP Rookies Cup seems to be effective to improve riders' performance, so that those riders involved in the program got better results than the rest, and these changes seem not to be related to maturation itself in a so small period of time in which no significant body changes were observed. So, it is suggested that a few training camps focused on improving overall fitness can evoke further improvements in young athletes, specifically in their racing result despite the fact that no statistically significant improvements could be found in physical fitness. According to the bigger gains observed in CMJ and handgrip strength specifically, we suggest that motorcycling riders should pay particular attention to strength training, specially to the musculature of the forearm, and the lower-body, since, during the conduction there takes place great number of constant changes of the position that the riders realizes on the motorcycle, due to the variations on the position and line during the races. The specific exercises for strength training should be similar to the skills of conduction, such as specific training on mountain bike (facilitated) or motocross (loaded), at the same time specific exercises can be developed in the gym using loaded handlebars on the top of unstable platforms or using specific machines (e.g. Riprow machine -24-). In addition CORE exercises should be included, as well as stretching exercises. Nevertheless, further studies must address deeper into other specific aspects that could take part in the context, i.e. technical aspects like static and dynamic balance or psychological variables like reaction time, concentration, or self-stem and perceived stress.

Disclosure of interest

The authors declare that they have no competing interest.

Acknowledgements

We want to thank DORNA organization for the permission to carry out the study.

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