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ORIGINAL RESEARCH

Association between motor competence, and the rating of perceived exertion in male young adults

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Abstract

The purpose of this study was two-fold: (i) to analyze the relationship between motor competence (*i.e.*, a person's ability to be proficient in different gross motor skills) and the rating of perceived exertion (RPE), which represents the physiological and psychological responses during training, in young adults, and (ii) to compare RPE between participants with high and low motor competence. Forty-eight male young adults (22.01 ± 2.43 years) participated in this study. Participants were randomly divided into several teams of three players to perform a small-sided game for 25 min (Goalkeeper + 2 × 2 + Goalkeeper) in which the RPE was collected. Then, motor competence was assessed through six tests assessing three main components: stability (Jumping Sideways and Shifting Platforms); locomotor (Standing Long Jump and Shuttle Run), and manipulative (Velocity of Ball Kicking and Throwing). Motor competence was negatively associated with RPE (r = −0.64; $p < 0.001$). Moreover, locomotor, stability, and manipulative components were negatively associated with RPE (all, $p < 0.05$). Furthermore, upon comparing groups with low and high levels of motor competence, we observed significantly higher RPE values ($p < 0.001$; $d = 0.32$) in the low motor competence group. The findings from this study suggest that individuals with higher levels of motor competence may report a lower RPE during exercise. This information is valuable for coaches as improving levels of motor competence may potentially lead to increases in on-field performance.

Keywords

Internal load; Exercise; Intensity; Youth; Sport; Small-sided games

1. Introduction

Motor competence (MC) encompasses the development and performance of a wide range of human movements [1, 2] comprising locomotor (such as galloping, leaping, or vertical and horizontal jumping), stability (involving dynamic and static balance), and manipulative skills (such as catching, throwing, or kicking) [3–5]. These skills are essential for the acquisition and refinement of specialized movements, thus MC is a comprehensive term that is related to movement development and performance and has been understood as a person's ability to be proficient in locomotor, stability, and manipulative gross motor skills [6].

Over the past decade, there has been increasing evidence highlighting the importance of MC in fostering healthy lifestyles throughout the lifespan [7]. Research has shown that MC is positively associated with higher levels of physical activity [7, 8], movement quality, energy expenditure, and object control skills [9]. Furthermore, MC has been found to have a positive impact on cognitive performance [10], and has been associated with sports participation [11]. To assess MC, the Motor Competence Assessment (MCA) battery test has been previously utilized. Silva and colleagues [5] performed a study to assess MCA reliability, and their results demonstrated that it is a reliable tool for assessing youth volleyball players' fundamental movement skills.

Even though MC is an important topic regarding its relation to locomotor, stability, and manipulative abilities, there have been limited studies focusing on assessing MC in young adults [5, 9, 12]. For instance, Cantell *et al.* [12] examined whether individuals with low MC levels achieve age-adequate fitness and health. Their findings indicate that individuals with lower levels of MC presented lower levels of health and physical fitness compared to those with higher levels of MC. Moreover, an association between MC and physical fitness in adolescents (in female but not in male participants) has been previously observed [13]. Additionally, a strong positive correlation has been observed between MC and energy expenditure [9]. Lastly, it is suggested that developing motor skill competence is important for maintaining and improving good levels of physical activity during adulthood [7].

Monitoring load is essential in sports to comprehend the training process, its adaptations, and to reduce the risk of injuries [14]. Training load can be categorized into external or internal [15]. The external load can be assessed by a wide range of measures and metrics, such as global positioning system derived units, force, resistance level, and work [16]. On the other hand, internal load pertains to the biological aspects of the player, encompassing physiological and psychological responses during training or competition [14, 17, 18]. It represents the measurement of the physiological response concerning the external load [16]. Among the different methods of measuring internal load, RPE is widely employed to quantify task intensity [18, 19]. RPE is measured using a scale that evaluates the perceived intensity of an activity, task, or exercise [17, 20]. It is recommended to be applied approximately 30 minutes after the end of the training session to avoid misjudgments solely based on the last exercise performed [21]. Moreover, due to its simplicity and easiness of comprehension, RPE can be applied across diverse populations and age groups [14, 20]. It is also employed at different levels of skills/expertise in sports, from youth to elite athletes [22].

In the last few years, numerous studies have investigated football performance and its relationship with different variables, such as reaction time, MC, and decision-making [23, 24]. More recently, there has been increased research interest in sports, particularly concerning internal load [15, 25]. For instance, studies have found a positive association between the internal load experienced by team sport athletes during training and matches with their playing performance [26]. Moreover, elite football players' external load (distance, impacts, and accelerations) has been linked to the RPE [25]. Some researchers argue that monitoring internal load is indispensable for assessing the individual adaptation to training programs (or exercise drills), determining the need for recovery between sessions, and minimizing the risk of overreaching, overtraining, and associated injuries [15]. Scherr *et al*. [27] have also reported strong associations between RPE and heart hate (r = 0.74; $p < 0.001$) and blood lactate levels (r = 0.83; $p < 0.001$).

While MC has been considered the foundation for all types of movements [6], the relationship between adults' MC and internal load during football drills remains unknown. To the best of our knowledge, no previous investigations have explored the relationship between these two variables. Understanding this relationship could offer valuable insights for coaches to improve their training sets, improve performance, and minimize effort load. Since load perception is individual, tailored training programs can be designed to meet the specific needs of players. Hence, this study aimed to analyze the association between MC and RPE in young adults. Furthermore, it was also analyzed the internal load and the three main components of MC, which include stability, locomotor, and manipulative levels. In this investigation, we are also interested to explore potential differences in perceived exertion between individuals with low and high MC levels. Based on the previous studies [25–28], it was hypothesized that there would be a positive association between MC, its components, and internal load. Furthermore, in line with previous studies [25–28], we also expect that participants with higher levels of MC will report higher levels of RPE.

2. Materials and methods

2.1 Participants

The sample size was determined using the G*Power v 3.1.9.7 [29] software (Kiel University, Kiel, Germany), considering the following parameters: Cohen's effect size of 0.40 for correlation bivariate normal model, error probability $\alpha = 0.05$, and $\beta = 0.80$. This calculation resulted in a sample size of 37 participants. A total of forty-eight male young adults (mean age 22.01 ± 2.43 years) were conveniently recruited from the University to participate in the investigation. The inclusion criteria were as follow: (a) absence of injuries or illness within the last four consecutive weeks; (b) previous experience with football small-sided games (SSG) and a minimum of 1 year of playing football; (c) all participants being amateur athletes; and (d) enrollment in a Sports Science undergraduate course. Participants were also divided into two groups based on their MC levels, categorized as Low MC and High MC, using the median value as a threshold, as previously suggested [2]. Individuals with injuries, limitations, or taking medication that could potentially influence the outcomes of the current investigation, as well as professional athletes were excluded from participation.

2.2 Procedures

Participants were instructed to refrain from engaging in strenuous exercise for 24 hours prior to the testing sessions. On the day of the testing, participants arrived at the pitch 30 minutes before the scheduled start time. They were informed about the protocol details and instructed regarding the RPE scale. However, participants were not informed about the specific aim of the study to avoid bias. To ensure participants had a clear understanding of the RPE scale and its correct usage after the SSG, a familiarization session was conducted. During this session, the instructional set was presented to participants as the anchoring procedures for using the RPE accurately [30].

Following the familiarization session, which was performed individually with each participant, a standardized 10-minute warm-up comprising dynamic stretching exercises was performed. Subsequently, the SSG took place. Thirty minutes after the SSG finished, each participant was asked individually "How intense was your session?" to obtain their RPE value. The Borg Category Ratio (CR-10) was printed on paper and provided to participants to assist them in reporting their perceived level of effort [18].

All participants were evaluated regarding their MC two days after the training session. The evaluations were conducted in small groups, with approximately five participants per task, at the University facilities. The examiner responsible for administering the tests was a certified professional with prior experience in administering the Motor Competence Assessment (MCA) battery. The testing procedure was performed accordingly to the authors' guidelines [2, 31] and followed a specific order (1) stability, (2) locomotor, and (3) manipulative components with a 1-minute resting interval between tests. All data were collected in 2021.

2.3 Tasks and instruments

2.3.1 Small-sided game (SSG)

Prior to data collection, the players were divided into sixteen teams, which were assigned to play in a randomized order (*i.e.*, team A, team B, team C, team D, *etc.*). This randomization was done to guarantee a balanced distribution of participants' performances. The game sessions were also performed in a randomized order (*i.e.*, team A versus team D and, team B versus team C), thus each team played only one time (duration = 25 minutes; adapted from Abrantes *et al*. [32]).

The game format consisted of six participants, with three on each team (Goalkeeper + 2 × 2 + Goalkeeper). To maintain continuous play and minimize disruptions, several balls (n = 10) were strategically placed around the playing area and promptly replaced when necessary. The session was conducted at 10 AM, with an average temperature of 20 degrees Celsius degrees. The playing area was an artificial grass pitch measuring 20 m × 30 m, marked with standard landmarks. The objective of each game was to outscore the opponents, and all the SSGs followed the official football rules, except the offside.

2.3.2 Motor competence assessment (MCA)

The MCA was administered according to the protocol previously published [2, 31]. The reliability and validity data have been documented in the literature [31], showing excellent values (ranging from 0.999 to 1.000) for all models. Rodrigues *et al*. [31] have also outlined the MCA scoring method. All tests included are quantitative and product-oriented, with no noticeable ceiling effect and with feasible execution. This instrument was specifically designed to measure MC and comprises six tests that evaluate three main components—Stability: Jumping Sideways (JS) and Shifting Platforms (SP); Locomotor: Standing Long Jump (SLJ) and Shuttle Run (SHR), and Manipulative: Ball Kicking Velocity (BKV) and Ball Throwing Velocity (BTV). Subsequently, the sample was divided into two groups using the median values (50th percentile of the normative values for the Portuguese population) [2], resulting in the formation of two groups: Low MC and High MC.

Following data collection, all data raw scores were transformed into percentiles accordingly to the Portuguese normative values [2]. Subsequently, the sample was divided into two groups using the median values (50th percentile of the normative values for the Portuguese population) [2], resulting in the formation of two groups: Low MC and High MC.

A. Jumping Sideways

Participants performed a sideways jump over a wooden beam (60 cm length × 4 cm high × 2 cm width), with the two feet together, as fast as possible for 15 seconds. Each correct jump scored one point and the best result over two trials was considered.

B. Shifting Platforms

Participants moved laterally for a duration of 20 seconds while using a pair of wooden platforms (25 cm × 25 cm × 2 cm). A two-point score was granted for every successful transfer made from one platform to the other (one point for each step—passing the platform and moving the body to the platform). Participants were given two trials and only the best score was considered.

C. Standing Long Jump

Participants executed the jump with utmost effort starting with both feet aligned together. The distance covered was measured by the difference between the starting point and the position of the heel of the foot closest to the starting point following the jump (measured in centimeters)—the farthest distance traveled of three attempts was used for data analysis.

D. Shuttle Run

Participants sprinted with maximum velocity towards a line placed 10 meters apart, picking up a wooden block, running back, and placing it beyond the starting line. Then ran back to retrieve the second wooden block and carry it back across the finish line. The highest score achieved over two attempts was considered, based on the time taken to complete the task.

E. Ball Kicking Velocity

Participants kicked a football ball (circumference, 64.0 cm; mass, 360.0 g) against a wall with maximum effort. The speed of each kick was quantified using a radar gun (Pro II STALKER radar gun) (measured in meters per second). It used the fastest speed of the three kicks.

F. Ball Throwing Velocity

Participants threw a sized tennis ball (diameter, 6.5 cm; mass, 57.0 g) with an overarm action against a wall with maximum effort. The speed of each throw was quantified in meters per second using a radar gun (Pro II STALKER radar gun). The fastest speed of three throws was used for data analyses.

Individual test results were then transformed into age- and sex-adjusted percentiles using the normative values of the MCA instrument [1, 2]. To calculate each MCA component score (Stability, Locomotor, and Manipulative), the average percentile position of the respective two tests was used. Finally, the total MC score was calculated as the average of the three MCA components.

Participants were given a demonstration of the proficient movement for the tests, followed by a familiarization attempt. Motivational feedback was provided during the testing session, but test-specific results were not communicated to participants. A thorough analysis of the instrument procedures can be found in the literature [2, 33].

2.3.3 Rating of perceived exertion

The RPE was assessed using the CR-10 scale [34]. Thirty minutes after completing the exercise session, participants were asked to rate their perceived level of exertion during the SSG using the CR-10 scale. Each participant had to select a number on the scale to rate their overall exertion during the exercise. A zero-rating score was associated with no exertion (nothing at all), while a score of 10 represented maximal exertion (extremely strong). To avoid non-valid values, all participants received prior familiarity with the scale, and their answers were provided individually using google forms on an iPad [30].

2.4 Statistical analysis

Descriptive analysis was employed to characterize participants, presenting the mean and standard deviation. The data normality was assessed using the Shapiro-Wilk test, and the equality of variances was examined using the Levene test. Pearson correlation was utilized to explore the relationships between MC (including tests, components, and age) and the RPE. Correlation coefficients <0.30 were considered weak, those between 0.30 and 0.70 were considered moderate and coefficients >0.70 were considered strong. To compare MC levels, the independent *t*-test was used, and Cohen's *d* ((mean 1–mean 2)/pooled standard deviation) as the index of effect size (considering *d*'s of large *d*, >0.8; moderate *d*, between 0.8 and 0.5; small *d*, between 0.49 and 0.20; trivial *d*, <0.2) [35]. Statistical Package for Social Sciences version 29.0 (IBM Corp, Armonk, NY, USA), was used adopting an alpha level of significance of 5%.

3. Results

On average, participants reported a moderate RPE score of 3.77 ± 1.54, as classified in Table 1. The average percentile scores for the JS, SP SLJ and SHR tests were below 50% indicating lower performance levels in these tests. The locomotor and Stability MCA components showed average percentile scores below 50%, representing better proficiency in manipulative skills. On average, the total MC score was 41.16 ± 16.11%.

The associations between RPE and the outcomes from the MCA protocol (JS, SP, SLJ, SHR, BTV, BKV, Locomotor, Stability, Manipulative, Total MC) are presented in Table 2 using Pearson Correlation. RPE showed negative correlations with SHR, BKV, Locomotor, Stability, and Manipulative, and Total MC. On the other hand, Total MC was positively associated with SLJ, SHR, BTV and BKV tests, and locomotor, stability, and manipulative components.

Anthropometrical parameters (age, height and BMI) and stability did not show differences between MC levels (Table 3). On the other hand, participants with higher levels of MC exhibited lower scores in RPE ($p = 0.001$), higher proficiency in locomotor skills ($p = 0.010$), manipulative abilities ($p = 0.010$), and total MC ($p = 0.001$).

Finally, another analysis was conducted to examine the relationships between RPE and MC, regarding MC levels (Table 4). The findings revealed that regardless of the MC level, there was a significant negative correlation between RPE and Total MC. Notably, the JS was found to be associated with RPE only in the higher MC level.

4. Discussion

The present study analyzed the relationship between MC and RPE in young adults, while also comparing RPE and MC variables among participants with high and low MC. Contrary to the initial expectations, MC was negatively associated with RPE (*i.e.*, the higher the MC, the lower the perceived effort reported by participants 30 minutes after the SSG). Considering that MC represents the primary requirement for movement execution, encompassing fundamental movements and being associated with higher levels of physical activity [7, 8], movement quality and energy expenditure [9], and sports participation [11], it is understandable that participants with higher MC experience better physiological and psychological adaptations, leading to lower perceptions of effort. These findings align with the study by Kovářová *et al*. [36], which observed differences in the perception of exertion among groups with different levels of practice and experience. Furthermore, these results highlight the importance of monitoring RPE for assessing individual adaptation to the training programs, as emphasized in the existing literature [15].

The association between higher MC values and good levels of physical fitness has already been noticed [7]. For instance, good levels of motor skills are acquired with practice and repetition, leading to improvements in physical and cardiorespiratory capacities [6]. Costa *et al*. [37] also highlighted that low MC could act as a barrier to achieving additional and transitional sports skills (required in many sports science degrees). These skills are essential for learning sports and performing team sport-specific motor tasks. Furthermore, Utesch & Bardid [6], in a systematic review with meta-analysis, verified a moderate to largely positive relationship between MC and physical fitness across different age groups, with the association becoming stronger as individuals mature. This indicates that individuals become better at accurately assessing their exertion as they grow older. On the other hand, players with high MC can benefit from increased exercise difficulty, as it will provide a greater challenge and help improve their performance. This understanding allows coaches to create more effective and individualized training programs based on players' specific MC levels.

Considering these findings, coaches can tailor training sessions accordingly to players' MC level. For players with lower MC, coaches can adjust the exercise difficulty to prevent excessive levels of effort. On the other hand, players with high MC levels can benefit from increased exercise difficulty, as it will provide a greater challenge and could help improve their performance. This understanding allows coaches to create more effective and individualized training programs based on players' specific MC levels. The development of MC (*i.e.*, neuromuscular coordination and control required to meet a wide range of movement goals) plays a critical role in the long-term development of health- and performance-related physical capacities (*e.g.*, muscular strength and power, muscular endurance, and aerobic endurance. Previous research [38] examined the relationship between functional MC and physical military readiness among Army Reserve Officer Training Corps cadets. Results showed a strong correlation between functional MC and physical military readiness, with low levels of functional MC serving as a significant predictor of failure in the Army Reserve Officer Training Corps. Based on these findings, the authors concluded that the development of MC could be important and may increase the physical military readiness of future military cadets.

Silva *et al*. [5] found that MCA is a reliable test to assess young adults' MC. Also, the study found that volleyball players with higher MC levels learned complex motor skills more easily than those with lower MC. While the use of physiological measures such as heart rate or oxygen consumption is

TABLE 1. Means and standard deviations for MC components and session training load.

Variables	Mean	SD	95% CI
Sample characterization			
Age (yr)	22.01	2.43	21.30; 22.72
Height (m)	1.75	0.14	1.71; 1.79
Body mass (kg)	83.01	9.16	80.35; 85.67
BMI (kg/m^2)	27.83	5.68	26.18; 29.48
RPE			
CR-10 Borg Scale (A.U.)	3.77	1.54	3.32; 4.22
MCA tests			
JS (%)	49.83	25.36	42.47; 57.19
SP (%)	35.51	32.33	26.12; 44.90
SLJ (%)	35.93	36.06	25.46; 46.40
SHR (%)	30.96	24.94	23.72; 38.20
BKV (%)	60.17	39.37	48.74; 71.60
BTV (%)	58.49	41.43	46.46; 70.52
MCA components			
Locomotor (%)	32.97	26.03	25.41; 40.53
Stability (%)	41.70	22.52	35.16; 48.24
Manipulative (%)	56.43	40.75	44.60; 68.26
Motor Competence (total MC) (%)	41.16	16.11	36.48; 45.84

Note: BMI: body mass index; RPE: rating of perceived exertion; A.U.: arbitrary units; JS: jumping sideways; SP: shifting platforms; SLJ: standing long jump; SHR: shuttle run; BTV: ball throwing velocity; BKV: ball kicking velocity; MCA: Motor Competence Assessment; SD: Standard Deviation; CR-10: Borg Category Ratio; CI: confidence interval.

TABLE 2. Associations among RPE and outcomes from the MCA battery test.

	RPE	JS	SP	SLJ	SHR	BTV	BKV	Locomotor	Stability	Manipulative	MC
RPE	1.00										
JS	−0.15	1.00									
SP	−0.26	0.14	1.00								
SLJ	−0.24	0.28	0.25	1.00							
SHR	−0.34*	0.14	0.22	0.39*	1.00						
BTV	−0.29	−0.28	−0.23	−0.27	−0.17	1.00					
BKV	−0.40*	−0.19	−0.27	−0.34*	−0.04	0.91*	1.00				
Locomotor	−0.33*	0.25	0.28	0.90*	0.78*	−0.24	−0.21	1.00			
Stability	−0.32*	0.67*	0.81*	0.29	0.27	−0.34*	−0.31	0.34*	1.00		
Manipulative	−0.38*	−0.22	−0.27	−0.31	−0.06	0.97*	0.98*	−0.20	−0.33*	1.00	
MC	−0.64*	0.25	0.28	0.43*	0.53*	0.49*	0.53*	0.57*	0.33*	0.54*	1.00

*Note: *$p < 0.05$; RPE: rating of perceived exertion; JS: jumping sideways; SP: shifting platforms; SLJ: standing long jump; SHR: shuttle run; BTV: ball throwing velocity; BKV: ball kicking velocity; MC: motor competence.*

TABLE 3. Comparison between MC levels and RPE.

MCA Components	MC Level	N	Mean	SD	*t*	*p*-value	Cohen's *d*	95% CI
Age (yr)	Low MC	25	22.38	2.42	1.11	0.272	0.33	21.67; 23.09
	High MC	23	21.59	2.43				20.88; 22.30
Height (m)	Low MC	25	1.72	0.13	−1.51	0.141	0.43	1.68; 1.76
	High MC	23	1.78	0.15				1.74; 1.82
Body mass (kg)	Low MC	25	84.53	9.40	1.15	0.260	0.38	81.80; 87.26
	High MC	23	81.46	8.81				78.90; 84.02
BMI (kg/cm^2)	Low MC	25	29.19	5.47	1.78	0.080	0.52	27.60; 30.78
	High MC	23	26.30	5.63				24.67; 27.93
Locomotor (%)	Low MC	25	23.84	20.45	−2.61	0.010	0.80	17.90; 29.78
	High MC	23	43.12	27.38				35.17; 51.07
Stability (%)	Low MC	25	38.08	20.55	−1.27	0.210	0.39	32.11; 44.05
	High MC	23	46.77	24.21				39.74; 53.80
Manipulative (%)	Low MC	25	44.63	38.41	−2.68	0.010	0.79	33.48; 55.78
	High MC	23	74.28	36.37				63.72; 84.84
Motor Competence (%)	Low MC	25	32.29	9.77	−7.11	0.001	2.01	29.45; 35.13
	High MC	23	54.02	11.19				50.77; 57.27
RPE (A.U.)	Low MC	25	5.28	1.70	4.71	0.001	0.32	4.79; 5.77
	High MC	23	3.30	1.07				2.99; 3.61

*Note: *p < 0.01; MCA: motor competence assessment; BMI: body mass index; RPE: rating of perceived exertion; A.U.: arbitrary units; SD: Standard Deviation; MC: motor competence; CI: confidence interval.*

TABLE 4. Associations between ITL and outcomes from the MCA battery test, regarding MC levels.

	RPE	JS	SP	SLJ	SHR	BTV	BKV	Locomotor	Stability	Manipulative	MC
Low MC											
RPE	1.00										
JS	0.16	1.00									
SP	−0.24	0.17	1.00								
SLJ	−0.10	0.07	−0.04	1.00							
SHR	−0.11	−0.05	−0.06	0.66*	1.00						
BTV	−0.32	−0.57*	−0.36	−0.43	−0.31	1.00					
BKV	−0.40	−0.43	−0.45*	−0.45	−0.15	0.91*	1.00				
Locomotor	−0.08	0.00	−0.06	0.95	0.88*	−0.37	−0.29	1.00			
Stability	−0.18	0.73*	0.78*	−0.03	−0.07	−0.61*	−0.56*	−0.05	1.00		
Manipulative	−0.36	−0.46*	−0.42	−0.42	−0.14	0.98*	0.98*	−0.27	−0.58*	1.00	
MC	−0.44*	−0.02	−0.02	0.34	0.45*	0.54*	0.59*	0.45*	−0.03	0.60*	1.00
High MC											
RPE	1.00										
JS	−0.47*	1.00									
SP	−0.22	0.09	1.00								
SLJ	−0.17	0.37	0.34	1.00							
SHR	−0.18	0.17	0.26	0.24	1.00						
BTV	0.09	−0.25	−0.30	−0.37	−0.37	1.00					
BKV	0.09	−0.24	−0.49*	−0.49*	−0.35	0.90*	1.00				
Locomotor	−0.22	0.35	0.38	0.87*	0.68*	−0.47*	−0.54*	1.00			
Stability	−0.40	0.61*	0.83*	0.39	0.31	−0.40	−0.54*	0.45*	1.00		
Manipulative	0.06	−0.28	−0.42	−0.47*	−0.39	0.96*	0.97*	−0.55*	−0.55*	1.00	
MC	−0.40*	0.40	0.45*	0.40	0.34	0.33	0.22	0.47*	0.53*	0.24	1.00

*Note: *p < 0.05; RPE: rating of perceived exertion; JS: jumping sideways; SP: shifting platforms; SLJ: standing long jump; SHR: shuttle run; BTV: ball throwing velocity; BKV: ball kicking velocity; MC: motor competence.*

typically necessary, it appears that young adults with higher levels of MC may possess an enhanced ability to perceive and report their physical exertion levels (see Table 3). Thus, it is expected that individuals with lower levels of MC may experience higher levels of RPE. As previously mentioned, MC reflects the development and performance of movements and activities, encompassing both neural and physical changes that occur during the learning process. For instance, long-term reorganization processes occur in the brain (*e.g.*, Rosenkranz *et al*. [39]), which show increased recruitment of corticospinal output and reduced intracortical inhibition. Furthermore, it is known that practice improves movement performance and reduces the energy cost per unit of work [40]. Therefore, it is possible that levels of perceived exertion (*e.g.*, RPE) for the same task may be lower after practice and improved MC. Interestingly, Haapala *et al*. [41] reported a negative association between MC and VO_2 during walking and running at specific intensities in children. These findings suggest that MC is related to physical fitness (*i.e.*, higher MC is associated with a lower VO_2). Since levels of VO_2 and RPE increase concurrently as the intensity of exercise increases [27], it could be postulated that higher levels of MC are associated with a lower perceived level of exertion during a task, which aligns with the main finding of the present study. Therefore, obtaining consistent data when evaluating sports athletes is essential to understanding the internal training load and avoiding excessive fatigue exposure, thus reducing the risk of injuries and overtraining.

Despite the important findings, the current investigation had some pitfalls. Firstly, the participants consisted exclusively of young adults in sports science programs, which may restrict the generalizability of the findings, even though the results were compared to normative values of the Portuguese population [2]. In addition, the validity and reliability were not specifically tested in this participant group, and they should be considered in future research. Furthermore, researchers failed to use other assessment tools (*i.e.*, reaction time and decision-making) or technic-tactical evaluation which could provide a more comprehensive understanding of the result. Finally, the actual physiological load was not measured by heart rate or blood lactate concentration during the SSG. Therefore, future studies should consider replicating this study's protocol in other group samples, including a control group or a group of individuals mostly sedentary or not performing any sports, and adding physiological variables related to physical efforts such as heart rate, blood lactate, and oxygen consumption. This would allow the examination of whether sports participation is associated with higher MC, as it has been postulated.

5. Conclusions

The planning of a training program generally aims to improve different aspects that are linked to better performance, allowing coaches to develop athletes' physical and motor abilities. Therefore, our results support the idea that higher levels of MC are associated with lower levels of RPE, probably generating a better response regarding physical effort. Notably, participants with higher levels of MC outperformed players with lower levels of MC, and we also observed moderate associations between MC levels and RPE. This finding holds significant value as RPE serves as a safe and inexpensive tool that enables widespread assessment of athletes across different age groups. Nevertheless, further research is necessary to fully understand and validate the relationship between MC and its components in other age groups and sporting contexts. Finally, the take-home message of this manuscript is that the selection of internal training load measures, which support and optimize training programs, should take into consideration the athletes' level of MC.

AVAILABILITY OF DATA AND MATERIALS

No new data were created or analyzed in this study. Data sharing does not apply to this article due to the Portuguese general data protection law.

AUTHOR CONTRIBUTIONS

FSF—conceptualization and methodology, FSF—project administration; VTH, NC, RW, JL and PM—investigation; CTM, AFS and DS—formal analysis; DS—resources; VTH, RO, NC, AFS and RW—writing, reviewing and editing; FSF, AFS and RO—supervision. All authors have read and agreed to the published version of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was conducted in accordance with the Declaration of Helsinki and approved by the Instituto Piaget ethics committee (P12-S21-21.06.22). All players were informed about study procedures and oral and written consent were obtained from the participants.

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CONFLICT OF INTEREST

The authors declare no conflict of interest. Rafael Oliveira is serving as one of the Editorial Board members of this journal. We declare that Rafael Oliveira had no involvement in the peer review of this article and has no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to GG.

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