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Age-dependent Knee Joint Isokinetic Profile in Professional Male Soccer Players

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ABSTRACT

Background: The knee-joint isokinetic profile (KJIP) injury risk factor may be modulated by chronological age, however, comparative data for elite male soccer players aged 25 years and older is lacking. **Objective:** To describe and compare the knee-joint isokinetic profile (KJIP) according to the chronological age of professional male soccer players. **Method:** In a cross-sectional study design, sixty-three soccer athletes from the first Chilean soccer division (A-series) were divided into younger and older groups (age ≤ 25 years; n = 35 and age > 25 years; n = 28, respectively). In both groups the IPKJ was assessed at 60°.s-1 in concentric mode. **Results:** The older group had lower extensor peak torque ($p < .05$). The younger group showed correlations between flexors peak torque and extensors mean power ($p < .001$). In the older group, flexors peak torque and flexors mean power were correlated. The flexors peak torque, total work, and mean power symmetric index (SI) exhibited values > 10 % for both groups. The extensors SI showed values > 10 % for mean power, although only in the older group. **Conclusion:** Several differences in the KJIP were noted between professional male soccer players aged ≤ 25 years and > 25 years. Current results offer injury prevention insights, discussed in the current manuscript.

Key words: Physical Conditioning, Human, Muscle Strength, Team Sports, Athletic Performance, Physical Fitness, Musculoskeletal and Neural Physiological Phenomena

INTRODUCTION

Professional male soccer players suffer 8.1 injuries per 1 000 hours of training and match exposure, (López-Valenciano et al., 2020) costing €500 000 per player when injured for one month. (Ekstrand, 2013) The most frequent location of injuries is the lower limb (6.8 injuries per 1 000 hours), (López-Valenciano et al., 2020) with the thigh (e.g., muscle strain) and knee (e.g., ligament tear) as the most commonly injured. (Junge & Dvorak, 2004; Pfirrmann et al., 2016) Several preventive efforts have been made to identify injury risk factors for such areas. However, male soccer players' knee injury rates continue to rise (Roth & Osbahr, 2018). Nearly half of non-contact anterior cruciate ligament (ACL) injuries in male soccer players occur during deceleration or cutting maneuvers (47%) (e.g., change-of-direction). (Della Villa et al., 2020). This indicates that active stabilizer muscles may have a key role in helping to control these maneuvers. Further to this, muscle imbalance (antagonist/agonist strength ratio) and strength deficits at the knee joint may be associated with hamstring tears, (Croisier et al., 2008), increased risk of ACL injuries, (García-Luna et al., 2020,) and reduced athletic performance, including tackle and jumping (i.e., heading) success (Wing et al., 2020). The latter has become a critical physical fitness marker of performance in male soccer players (Arnason et al., 2004). Moreover, a greater number of team injuries correlates inversely with team positioning at the end of a competitive league (Arnason et al., 2004; Martin Hägglund et al., 2013). Thus, any test measure which can potentially identify athletes at a greater risk of injury is essential to aid practitioner decision-making when considering whether targeted training interventions are necessary.

Isokinetic profiles are frequently used to identify the factors related to injuries of joints (Siddle et al., 2019; Torres-Banduc et al., 2021), including the knee (Croisier et al., 2008; Stastny et al., 2018). Indeed, the knee-joint isokinetic profile (KJIP) may predict injury risk using markers such as

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peak torque between agonist/antagonist muscles (i.e. values < 55% denote increased risk of injury) (Croisier et al., 2008; Grygorowicz et al., 2017), concentric or eccentric-peak torque concerning body mass (peak torque/body mass) (Lee et al., 2018), muscle power (Saç, 2018), and/or symmetry (Beato et al., 2021) or dominance indices (DeLang et al., 2021). In addition, the KJIP may be able to provide threshold values included in "return to play" decisions after a knee injury (Schons et al., 2019). In addition, isokinetic power is considered a prerequisite for many essential actions in soccer, such as tackling, jumping, and shooting (Wing et al., 2020). Moreover, the training level may be predicted by isokinetic torque and power independently. (Toskić et al., 2020), helping to discriminate between athletes within the same sport (Torres-Banduc et al., 2021). The isokinetic total work capacity of the hamstring also differs between soccer players of different countries and levels (Śliwowski et al., 2020). Therefore, isokinetic profiles have the potential to provide meaningful data for soccer players.

The KJIP and associated external and internal injury risk factors may be modulated by chronological age (Bahr, 2005). For example, Gür et al. (1999) investigated the effects of age on the KJIP in elite male soccer players aged > 21 compared to ≤ 21 years of age. The older group noted greater values of KJIP in the dominant leg, including eccentric and/or concentric peak torque of knee flexors and extensors and eccentric flexor/concentric extensor peak torque ratio. Similarly, Amato et al. (2001) compared the KJIP (i.e., extensor peak torque) in male soccer players aged 15 (183.6 N*m), 17 (212.7 N*m), and 20 years old (240.4 N*m). They noted the largest value in the older group ($p<0.05$). Furthermore, a recent study comparing KJIP between youth (i.e., mean age 17 years) and adult (i.e., mean age 25 years) male soccer players (Eustace et al., 2020) found higher peak torque values in the adult group. However, comparative data for elite male soccer players aged 25 years and older is lacking, which affects the data's external validity. This is particularly relevant considering that being aged > 25 years is a prognostic factor for hamstring muscle injury in soccer (Shalaj et al., 2020). Professional soccer players typically retire between their late 20s and mid-30s (Barth et al., 2021). Accordingly, the objective of this study was to describe and compare the KJIP (knee flexors and extensors peak torque, total work, mean power, flexor/extensor ratio, and symmetric index (SI), in both dominant and non-dominant legs) according to the chronological age of professional male soccer players. Considering previous studies (Eustace et al., 2020; Gür et al., 1999), we hypothesized differences in the KJIP in elite adult male soccer players according to chronological age.

METHODS

Study Design

Using a cross-sectional study design, the KJIP was assessed in professional (A-series) male soccer athletes during the pre-competitive period. In brief, after anthropometric assessment, the soccer athletes were evaluated at $60°.s^{-1}$ in an isokinetic device. The dependent variables that were measured and analyzed were peak torque, total work, mean power, knee flexor/extensor ratio and symmetric indexes (SI) of peak torque, total work, and mean power. The age group (younger, older) served as the independent variables.

Subjects

Using statistical software (G*Power, v3.1.9.7, Heinrich-Heine-Universität, Germany), the estimated total sample size was 52 participants. This number was obtained using a desired power (1-ß error) = 0.8, alpha-error < 0.05, and a medium effect size = 0.7 (considering a partial eta squared of 0.118) (Eustace et al., 2020). Considering possible dropouts, the minimal sample size was set at 28 participants per group.

The athletes were recruited during the pre-competitive period at the same place where they usually participated in regular soccer training sessions (1.5 h in the morning and 1.5 h in the afternoon, five days per week, for three weeks before inclusion in this study). Athletes in the younger group had three years, and the older group had 13 years of regular training and competition experience in the first Chilean soccer division (A-series). In addition to one weekly training match, both groups had similar weekly training schedules (e.g., loads) as reported by the technical staff of the soccer team.

The athletes were selected based on the following inclusion criteria: i) to be an official player in one of the soccer teams playing in the Chilean soccer series-A league; ii) free from injuries in the last four months before testing procedures included in this study. The athletes were excluded if they (i) inability to exert maximal effort during the testing procedures involved in this study or (ii) used prohibited substances (according to the Chilean soccer series-A league regulations) that may affect the results of the dependent variables of this study. The study was aligned with latest version of the Helsinki declaration. All participants read and signed an informed consent before the start of the study. The study design was approved by the ethics board of the Universidad de Las Américas, project ID: CEC_PI_2019037.

Procedures

During a 15-minute familiarization session (to increase testing reliability), the isokinetic tests were explained, a practice trial was performed, and instructions were given (i.e. avoid vigorous physical training the day before the testing session and to maintain their usual diet). The same research assistant, who was blinded concerning the group to which each participant belonged, carried out the familiarization and testing sessions, in the same laboratory, between 9 AM and 11 AM.

Anthropometric Evaluation

After removing their shoes, standing height and body mass was measured using a telescopic scale (SECA, model 220, Hamburg, Germany) and a calibrated mechanical scale (SECA, model 711, Hamburg, Germany), with a precision of 0.1cm and 0.1 kg respectively.

Isokinetic Evaluation

During the KJIP assessment, the participants were seated in the dynamometer to position their hip and knee joints at a ~90° angle. The strap was wrapped ~3 cm above the lateral malleolus of the athlete's ankle and at the thigh, waist, and chest. An effort was made to align the center of rotation of the knee joint and the dynamometer. All test protocols were measured at 60°.s-1, which provided a measure of maximal peak torque, noting that values obtained at faster speeds have shown reduced levels of reliability (e.g., 180 or 240°.s-1) (Huesa Jiménez et al., 2005).

The isokinetic measurements were performed using valid and reliable equipment (Biodex® Isokinetic Dynamometer, System 3 Pro, NY, USA) (Figure 1) with a precision of ±1%. Before maximal measurements, a 5-minute warm-up on a cycle ergometer at an intensity of ~70 watts was performed. In addition, the warm-up also comprised three submaximal repetitions of the isokinetic movements. Gravity correction procedures as per leg mass were applied before maximal testing (Daneshjoo et al., 2013). After 30 s of rest post submaximal repetitions, each participant performed a set of three maximal concentric knee extensions and flexions with dominant and non-dominant legs. Participants were encouraged to exert maximum effort using a standardized verbal guideline. One limb was measured before the contralateral limb, with order selected as per the bag-randomization method. Limb dominance was determined as the preferred leg to kick the soccer ball (Van Melick et al., 2017).

Description. Measurement of the knee-joint isokinetic profile in a representative male soccer player, during the concentric extensor pattern.

Therefore, the knee flexors and extensors from dominant and non-dominant legs were assessed, and the main outcome was peak torque (%) calculated as (peak torque [N*m]/body mass [Kg]) × 100. Secondary outcomes included i) total work (%) calculated as (total work [J]/body mass [Kg]) × 100, ii) mean power (W), iii) knee flexor/extensor ratio (%) calculated as (knee flexor peak torque [N*m]/knee flexor peak torque [N*m]) × 100, and iv) symmetric indexes (SI) (%) of peak torque, total work, and mean power, calculated as ([dominant limb - non dominant limb])/dominant limb) × 100.

Figure 1. Measurement of the IPKJ in the Biodex® Isokinetic Dynamometer

Statistical Analyses

The homogeneity of variances (Levene test) and the normal distribution of the data (Kolmogorov-Smirnov test) were confirmed ($p > 0.05$). Descriptive data are presented as mean ± SD. Considering three repetitions per test, only data with a coefficient of variation (CV) ≤10% were used in the analysis (Cormack et al., 2008). The difference between groups was assessed by independent samples t-test, and Hedges g was used to assess the effect size. The effect sizes were classified as: < 0.20 = trivial, 0.20–0.59 = small, 0.60–1.19 = moderate, 1.20–2.00 = large, and > 2.00 = very large (Hopkins et al., 2009). The Pearson's product-moment correlation coefficient (Pearson's r) was used to quantify the correlation between outcomes. The criteria to interpret the magnitude of the correlations were null (0.00–0.09), small (0.10–0.29), moderate (0.30–0.49), large (0.50–0.69), very large (0.70–0.89), nearly perfect (0.90–0.99), and perfect (1.00) (Hopkins et al., 2009). Statistical significance was accepted at $p < 0.05$. Finally, Jeffreys's Amazing Statistics Program (JASP) (version 0.14.1) was used for statistical analyses.

RESULTS

Sixty-three male soccer athletes participated in this study (mean ± standard deviation [SD]: age = 24.7 ± 5.6 years, body mass = 75.0 ± 7.8 kg, height = 1.76 ± 6.8 m, body mass index (BMI) = 24.1 ± 1.9 kg/m2). Considering previous findings (Barth et al., 2021; Eustace et al., 2020; Shalaj et al., 2020) the athletes were divided into younger group (age, ≤ 25 years; n = 35) and older group (age, > 25 years; n = 28) (Table 1). The analysis showed significant between-group differences for age (p <.001, g = 3.81), body mass (p <.001, g = 1.13) and BMI (p <.001, g = 1.13) (Table 1), with greater values for the older group.

The CV values for the knee extensor of the dominant and non-dominant leg were 4.4 ± 2.4% and 4.1 ± 2.5%, and for the knee flexor of the dominant and non-dominant leg were 4.7 ± 2.7 and 5.0 ± 2.5, respectively. The knee extensor peak torque was lower in the older group (dominant leg: p =.001, g = 0.82) (Table 2). No significant differences were observed for total work or mean power. However, the knee flexor/extensor ratio was <55% in the dominant and non-dominant legs of the younger group and the non-dominant leg of the older group (Table 2).

In the younger group, correlations were noted between knee extensor peak torque and mean power (r = 0.663,

Table 1. Basic descriptive characteristics of soccer athletes per group

	Younger (n=35)	Older (n=28)	*g*
Age (years)	20.31 ± 2.29	30.28 ± 2.90*	3.81
Body mass (kg)	71.51 ± 7.34	79.27 ± 5.97*	1.13
Height (cm)	175.22 ± 7.47	177.53 ± 5.67	0.34
Body mass index (kg/m^2)	23.28 ± 1.67	25.14 ± 1.55*	1.13

Values are mean±standard deviation. * = significant differences between groups (p<0.001); g=Hedges'g effect size

Table 2. Knee muscle flexors and extensors peak torque, total work, mean power, and knee flexor/extensor ratio in the dominant and non-dominant leg

	Younger group (n=35)		Older group (n=28)		Dominant£		Non-dominant£	
	Dominant	Non-dominant	Dominant	Non-dominant	*p-value*	Hedges'*g* effect size	*p-value*	Hedges'*g* effect size
Peak torque (%)								
Extensors	325.0 ± 38.9	319.0 ± 42.8	290.8 ± 44.0*	304.5 ± 45.9	0.001	0.82	0.202	0.32
Flexors	166.5 ± 40.8	161.2 ± 31.9	159.2 ± 27.0	156.3 ± 21.5	0.415	0.20	0.486	0.17
Total work (%)								
Extensors	359.8 ± 46.2	350.5 ± 56.3	335.8 ± 59.9	343.8 ± 63.0	0.077	0.45	0.657	0.11
Flexors	216.3 ± 47.3	214.8 ± 72.5	201.1 ± 37.3	199.0 ± 30.8	0.169	0.35	0.285	0.27
Mean power (W)								
Extensors	151.2 ± 29.2	149.1 ± 33.1	150.4 ± 27.2	158.7 ± 29.5	0.912	0.03	0.238	0.30
Flexors	89.3 ± 21.8	84.3 ± 23.0	88.9 ± 17.3	88.5 ± 14.6	0.945	0.02	0.406	0.21
Knee flexor/extensor ratio	53.3 ± 10.9**	50.6 ± 7.6**	55.4 ± 10.1	52.2 ± 9.2**	0.432	0.20	0.434	0.19

Values are mean±standard deviation. % = values relative to body mass; * = significant differences between groups (*p* = 0.001); ** = values <55% denotes the clinical cut-off point for increased risk of injury;£: the *P* (i.e., t-test) and g (Hedges) values were derived from between-groups comparisons

p <.001, dominant leg; r = 0.715, *p* <.001, non-dominant leg), and between knee flexor peak torque and knee extensor mean power (r = 0.525, *p* <.001, non-dominant leg) (Table 3). Moreover, knee extensor peak torque was correlated with knee flexor mean power (r = 0.364, *p* =.033, dominant leg; r = 0.602, *p* <.001, non-dominant leg), and knee flexor peak torque was correlated with knee flexor mean power (r = 0.858, *p* <.001, dominant leg; r = 0.851, *p* <.001, non-dominant leg) (Table 3). In the older group, knee extensor peak torque was correlated with knee extensor mean power (r = 0.857, *p* <.001, dominant leg; r = 0.863, *p* <.001, non-dominant leg), same as knee flexor peak torque and knee flexor mean power (r = 0.874, *p* <.001, dominant leg; r = 0.755, *p* <.001, non-dominant leg) (Table 3). No other significant correlations were noted in any group.

The knee flexor peak torque, total work, and mean power SI exhibited values > 10% for younger and older groups (Table 4). The knee extensor SI only showed values > 10% for mean power in the older group (Table 4). No between-group differences were noted for any SI marker.

DISCUSSION

The main objective of this study was to describe and compare the KJIP according to the chronological age of professional male soccer players. Lower knee extensor peak torque for the dominant leg was observed in the older group. In younger and older athletes, the peak torque and mean power correlated with the dominant and non-dominant legs for knee extensors and flexors. Younger and older athletes exhibited a SI > 10% for peak torque, total work, and mean power at the knee flexors, and older athletes had SI > 10% for peak torque in knee extensors. Our results complement previous findings of adults (Gür et al., 1999) and youth (Amato et al., 2001; Eustace et al., 2020) male soccer athletes, offering more information into knee injury risk and muscle performance according to age in soccer players. Indeed, in some sports like basketball (Gerodimos et al., 2003), the relationship between the KJIP (particularly of knee flexor/extensor ratio) and age may help assess athletes' risk of sustaining a knee/thigh injury. Current findings may contribute to practitioners planning exercise programs during training and rehabilitation. This is particularly relevant in sports with a high prevalence of knee injuries (Thacker et al., 2003) such as soccer, where most injuries occur at the knee (López-Valenciano et al., 2020; Pfirrmann et al., 2016).

One of the primary findings of this study was the lower peak torque of the extensor knee muscles of the dominant leg in the older group when compared to the younger group. This finding differs from previous studies, which have found higher peak torque values of knee flexor and extensor muscles at 30º.s-1 (Gür et al., 1999), 60°.s−1 (Amato et al., 2001), and 180°.s-1 (Amato et al., 2001; Gür et al., 1999), and 300º.s-1 (Gür et al., 1999), as well as greater extensor peak torque at 270°.s-1 in adults compared to young male soccer athletes (Eustace et al., 2020). The difference between our results and previous studies may be explained by including a group of older players (30-year average). In contrast, previous studies have compared youth (15-20 years) with adult player's with

Table 3. Correlations between peak torque and mean power

	Younger group (n=35)		Older group (n=28)	
	Mean power dominant leg			
	Extensor	**Flexor**	**Extensor**	**Flexor**
Peak torque dominant leg, extensor	0.663***	0.364*	0.857***	0.369
Peak torque, dominant leg, flexor	0.327	0.858***	0.297	0.874***
	Mean power non-dominant leg			
Peak torque non-dominant leg, extensor	0.715***	0.602***	0.863***	0.321
Peak torque non-dominant leg, flexor	0.525***	0.851***	0.304	0.755***

*** = $P < 0.001$; * = $P < 0.05$

Table 4. Isokinetic knee symmetry index (SI)

	Younger group (n=35)		Older group (n=28)		$p^{£}$		$g^{£}$	
	Extensor	**Flexor**	**Extensor**	**Flexor**	**Extensor**	**Flexor**	**Extensor**	**Flexor**
Peak torque SI (%)	8.74±8.46	**10.94±8.74**$^{€}$	9.65±7.43	**10.78±8.63**$^{€}$	0.659	0.942	0.11	0.01
Total work SI (%)	9.23±8.48	**13.58±9.98**$^{€}$	9.39±6.96	**13.34±8.62**$^{€}$	0.934	0.918	0.02	0.02
Mean power SI (%)	9.26±7.82	**13.67±10.84**$^{€}$	**10.55±7.96**$^{€}$	**12.80±11.88**$^{€}$	0.523	0.763	0.16	0.07

Values are mean±standard deviation. € = value>10% denotes the clinical cut-off point for increased risk of injury; g=Hedges'g effect size; £: the *P* (i.e., t-test) and g (Hedges) values were derived from between-groups comparisons.

a mean age of 25 (Amato et al., 2001; Eustace et al., 2020; Gür et al., 1999). In previous studies, muscular maturation may have played an essential role in improving the absolute strength of older soccer players compared to younger (under 20 years) (Amato et al., 2001; Gür et al., 1999). Additionally, training exposure or volume may influence the level of thigh muscle strength, as shown when comparing players from 14 to 18 years of age (Wrigley et al., 2012). As such, this may help explain the differences in our data and those who find higher knee peak torque across ages in soccer players up to 20 years. Another explanation for the lower-extensor peak torque found in the older group is the intensity sustained during training and match-play, which can be lower than the younger group; an issue already established in youth soccer players from 14 to 18 years (Wrigley et al., 2012). However, since we did not collect information about the intensity of training and match-play, further research about this issue on male soccer players over 25 is still required. Overall, our results should be considered by coaches to adjust the strength training of male soccer players, particularly to improve the strength of the knee extensors in soccer athletes over 25, considering the critical role of knee extensors in preventing ACL injuries and re-injuries (Kyritsis et al., 2016).

Our results revealed no significant differences between groups or legs in total work. Similar to our results, no significant differences in total knee flexor and extensor work have been found in elite male soccer players according to playing position (Śliwowski et al., 2017). This finding explains that total work may be less sensitive to age than peak torque. Total work aims to inform about the muscle's ability to generate strength over the entire range of movement. In the same line, the smaller extensor peak torque observed in the older group is compensated by a maintenance of the level of torque exerted during the range of motion measured. In contrast, the younger group would not have this ability (i.e., maximum torque is not being maintained through the full range of motion). Consequently, no significant difference in total work was found, whereas meaningful differences were evident for peak torque. On the whole, this should be considered when muscle endurance training is being programmed, considering individualized loads and exercises in terms of age and work performance.

We also found no significant differences between groups or legs in mean power, which differs from previous studies on male soccer players (Amato et al., 2001). Similar to those mentioned above regarding peak torque, and considering that Amato et al. (Amato et al., 2001) compared youth vs. adults (mean aged 18.6 years), the difference in our results may be explained by the age of the athletes evaluated, whereby the maturity may be a decisive factor in the differences found. Considering that isokinetic mean power is calculated as the total work divided by the time spent executing the test (Huesa Jiménez et al., 2005), our results show a significantly lower extensor peak torque in the older group. Still, greater mean power values than the younger group. Therefore, it seems logical to suggest that while the older group may have executed both knee extension and flexion faster than the younger group, the lower extensor peak torque values resulted in no significant differences in mean power—noting power is a product of both force and velocity. Overall, these results reveal that older soccer players may be able to compensate for reduced torque and total work with greater movement velocity during this test. The latter should be considered when the KJIP is analyzed, considering a comprehensive perspective between peak torque, muscle power, and total work.

The knee flexor/extensor ratio found no significant difference between groups. However, only the dominant leg of the older group showed the recommended ratio value (i.e., 55%) (Croisier et al., 2008; Grygorowicz et al., 2017), indicating, in particular, a larger than desirable intra-limb ratio value in younger players. Similarly to our study, Gür et al. (1999) found that age did not influence this conventional ratio. However, the values of this ratio in the groups were ≥ 55%. This difference can be explained by not testing the angular velocity of 60°.s-1. Instead, they evaluated isokinetic profiles at 30°.s-1, 180°.s-1, 240°.s-1 and 300°.s-1. A recent review has suggested the need for specific reference values according to the angular velocity selected when testing knee flexor/extensor ratio (Baroni et al., 2020), finding values ranging from 50 to 89% across different isokinetic speeds (i.e., 30°.s-1 to 360°.s-1). The difference between knee flexor/extensor ratio across different isokinetic speeds is explained because the hamstring muscles would have a greater capacity to generate strength at increased isokinetic velocities, considering that they usually work at high shortening velocities (Nunome et al., 2002). Considering the individualized nature of the ability to accelerate/deaccelerate during a movement, we recommend that each athlete's profile is actioned accordingly. Overall, and considering the differences in the extensor peak torque, attention must be taken to soccer players under 25 years, taking measures to prevent hamstring injuries. Therefore, further studies should be conducted considering isokinetic velocity and athletes' ages in line with this isokinetic ratio and re-evaluate its predictive value.

Regarding SI, peak torque, mean power, and total work of knee flexor muscle in both groups were > 10%, and only in the older group SI peak torque of knee extensor muscle showed the same value. The SI peak torque of knee extensor muscle in the older group found in our study differs from previous studies where values under 10% were found in the elite academy and professional male soccer players (Beato et al., 2021; Bishop, Coratella, et al., 2021). In addition, SI peak torque of knee flexor muscle differs from previous studies where values under 10% were found in professional adult male soccer players (Bishop, Coratella, et al., 2021). The fact that our results show an asymmetry predominantly in the peak torque of knee flexor muscles in both groups is relevant. It shows that its origin is not connected to age but other variables such as Chilean professional soccer training systems. Indeed, it has already been reported that there are differences in total hamstring work between the dominant and non-dominant leg between international and non-international elite male soccer players (Śliwowski et al., 2020). In other words, it is possible to consider that isokinetic variables associated with knee flexor muscles would make it possible to distinguish between different leagues and levels of soccer players, in addition to the possibility of injury. Additionally, it is crucial to establish that no significant differences between groups were found. This can be attributed to the large standard deviation concerning the mean asymmetry value. Due to the large standard deviation found, looking at asymmetry values in professional male soccer players is recommended on a case-by-case basis (Bishop, Lake, et al., 2021).

Muscle imbalance in concentric knee extension between the dominant and non-dominant limb is common in athletes (Della Villa et al., 2012; Jones & Bampouras, 2010). For example, Jones & Bampouras (2010) report an imbalance of ~10.5% between the dominant and non-dominant limbs in male athletes from various sports. Similarly, Della Villa et al. (2012) reported a mean deficit of ~12.5% in maximal peak torque between knee extensors in soccer players after anterior cruciate ligament surgery. Moreover, the SI is commonly reported to compare the injury risk between players of different competitive levels (DeLang et al., 2021). Nonetheless, few studies have reported the SI according to the age of professional soccer players. Our novel findings indicate that the mean power SI (%) of the knee extensor muscles was larger in the older compared to the younger group of soccer players ($p<0.05$). Therefore, older soccer players may have an increased risk of injury in the dominant extremity (~1.6 times) (DeLang et al., 2021). Indeed, increased muscle injury rates in professional soccer players have increased through chronological age (M. Hägglund et al., 2013). Current findings highlight the need for an efficient training process that helps to reduce the SI and, therefore, injury risk (Beato et al., 2021). However, Gokeler et al. (2017) mention that the SI can underestimate performance deficits in athletes, suggesting using complementary tests to determine the KJIP. Likewise, Jones & Bampouras (2010) also concluded that field tests might help detect imbalances between lower limbs. Still, the test choice depends on the specific strength quality that predominates in the sport (Jones & Bampouras, 2010). Future studies in this field should resolve these issues.

In younger and older athletes, we found that both muscle groups tested (i.e., flexors and extensors) have large and very large correlations between mean power and peak torque in the dominant and non-dominant leg (no other large and very large correlation was found). This result is similar to previous findings between isokinetic leg strength and power during different types of vertical jumps of male soccer players (i.e., strikers) (Buśko et al., 2018). Knee extensor peak torque is correlated with jump height, muscle power, and soccer performance (i.e., r = 0.79-0.80 between heading success and SJ and CMJ height) (Buśko et al., 2018; Wing et al., 2020). Therefore, balanced and meaningful knee extensor power and torque levels may favor younger and older soccer players during key actions requiring power torque (e.g., jumping, sprinting, cutting).

The primary limitation of this study relates to the concentric nature of isokinetic measurements. Indeed, eccentric or stretch-shortening cycle muscle actions were not assessed, and soccer players commonly perform these during training and competition. This precludes the full description and comparison of the KJIP according to the chronological age of professional male soccer players. Nonetheless, most studies related to the KJIP used a similar concentric assessment approach (Amato et al., 2001; Śliwowski et al., 2017; Śliwowski et al., 2020). This facilitates the comparison of findings across studies.

Strength and Practical Implication

The primary strength of this study is the sample size, sufficient to obtain 80% statistical power. Our findings illustrate that increased age (i.e., ≥ 25 years) in male soccer players entails lower knee extensors peak torque and greater extensor peak torque SI (>10%). Therefore, a focus is recommended on the monitoring and optimization for the torque of the knee extensor muscle group and to avoid biased knee flexor/extensor ratio, thus potentially helping to reduce knee injuries.

CONCLUSION

The KJIP differs according to the chronological age (≤25 years vs. >25 years) of professional male soccer players. The extensor peak torque is lower, and the extensor peak torque SI is greater (>10%) in older soccer athletes. Further, a large and very large correlation between peak torque and mean power was found for knee extensor and flexor in both younger and older soccer players. The chronological age of the soccer players did not affect the conventional knee flexor/extensor ratio. The tendency toward lower total work, and lower peak torque, although greater mean power in older than younger soccer players, should be considered for the planning of training programs.

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