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RESEARCH

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The isometric and isokinetic knee extension and flexion muscle strength profile of elite soccer players

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Abstract

Background This study aimed to further complete normative data sets for the strength profile of the thigh in soccer players by performing isometric and isokinetic measurements in a large sample per player position.

Methods In total, 364 soccer players were divided into subgroups according to their pitch position. All players performed isometric and isokinetic strength measurements during active competition period using an isokinetic dynamometer (System 3, Biodex®, ENRAF-NONIUS, New York, USA).

Results Isokinetic strength of m. Quadriceps was significantly ($p=0.023$) higher in strikers compared to central midfielders in both the dominant (+9%) and the non-dominant (+4%) leg. No further differences were found in isometric or isokinetic strength per playing positions.

Conclusions We have shown that strength profiles do not differ between playing positions on the field. This is valuable information for elite soccer high performance coaches and medical staffs aiming to improve daily training efficiency and rehabilitation of their players.

Keywords Soccer, Strength, Injury prevention, Rehabilitation

Introduction

In (professional) soccer, muscle injuries of the thigh are highly prevalent and may induce long term absence of players accompanied by intensive rehabilitation periods [1, 2]. Previous muscle injuries of the thigh are very likely to cause future injuries in the same or other lower limb muscles, if not monitored adequately [3]. This leads to further increased absence from training and competition [1]. It is evident that evaluation of the muscle strength profile of the thigh substantially provides important information for high performance coaches regarding the characteristics of their player group [4–6]. Especially in elite soccer teams this is an important tool to substantially reduce the risk of lower limb muscle injuries [7], which can be used to design injury prevention training programs and improve overall competitiveness of the team [1].

Assessment of the m. Quadriceps and m. Hamstrings strength in particular is of significant importance for soccer players because it provides information regarding maximal performance, lower limb biomechanics, and functional capacity during typical soccer tasks such as running and kicking [8]. In case of injury and

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rehabilitation, retraining of these muscle groups are major outcome measures in the decision process towards return-to-play [9, 10]. To assess the strength of m. Quadriceps and m. Hamstrings, isometric and isokinetic tests on a dynamometer are the most commonly used objective measures [11].

As early rehabilitation often involves isometric strength training, isometric strength variables at different knee angels are valuable in assessing rehabilitation progress [12]. Although functionally probably less relevant to isokinetic evaluation, isometric muscle strength measurements have been reported to have a high degree of standardization, easy to perform, induce lower physical stress and are considered very safe (i.e. low risk on injury during testing) for the participant [13, 14]. Under isometric test conditions, subjects perform a maximal knee extension (mainly involving the quadriceps) or knee flexion (mainly involving the hamstrings) usually for 3–4 s against a fixed resistance and knee angle. As such, isometric assessments are an important part of the complete strength profile of soccer players [6]. Because isometric measurements are also used to evaluate the force-length relationship of a muscle [15, 16], it is important to note to test every muscle at optimal (sarcomere) length. Surprisingly, isometric measurements are not frequently used to evaluate muscle strength profiles of elite soccer players, as the importance of such isometric testing often seems overlooked [17–20].

Isokinetic measurements on the other hand provide extended insights in individual dynamic muscle strength and muscle performance/fatigue profiles and are considered more functional [17, 21]. Here, subjects usually perform a series of 3–5 maximal eccentric and/or concentric contractions at a constant speed of 30° to 450°/Sec. [22]. Previous research focusing on isokinetic measurements in soccer players [17–20] has shown that the results of such measurements can be used as reference values for injury prevention, training and rehabilitation of soccer players. However, the studies conducted so far have included rather small sample sizes (n=39) [18, 20] or when large sample sizes were included (n=111) [19], these were divided into smaller subgroups (n=14–30) to accommodate different player positions. Although categorization in pitch position has provided further insights on possible clinical differences between player profiles, these smaller subgroups ultimately lead to a decreased external validity of the normative data for each subgroup. Burigo et al. [17] included a large sample size (n=582), but focused on the development of isokinetic cut-off values to predict future hamstring injury, rather than normative isokinetic data per player position. A similar study was conducted by Scoz et al. [33] in which 570 soccer players from different positions on the pitch were examined for different age-related effects on thigh muscle strength. Here, small effects of playing positions and a moderate effect of age on muscle strength in soccer players were shown. However, in order to deliver the most complete strength profile of the thigh in soccer players complementary analyses such as the ratio between m. Hamstrings and m. Quadriceps (H/Q ratio) are of great importance, because disbalances in the H/Q ratio significantly increase the risk for injuries in soccer players [23–25]. Furthermore, comparisons between the dominant and non-dominant leg (to evaluate strength imbalances) [4, 25], and investigations of the impact of age on the strength outcomes per player position are interesting factors to take into account: younger players may display lower strength outcomes compared to older teammates, making these younger players more prone to lower limb neuromuscular control and thus lower limb injuries [26, 27].

Therefore, the current study aims to further complete the normative data sets for the strength profile of the thigh, by performing isometric (at optimal m. Quadriceps and Hamstrings muscle length) and isokinetic measurements in a large sample of elite soccer players per player position including H/Q ratios and regression analyses to investigate age effects on these strength variables. We hypothesize that the strength profile of players will differ according to different player positions, as well as according to age and experience (younger vs. older players).

Materials & methods

Study design

This is a retrospective cohort study based on isometric and isokinetic data and clinical records of Belgian elite male soccer players from 2010 to 2021 performed by the Adlon Sports Medical Center (Hasselt University, Diepenbeek, Belgium). All players were active in the first Division A (Jupiler Pro League) or first Division B (Eerste Klasse B) of the Royal Belgian Football Association and were in possession of a professional player contract (~ 1–2 training sessions/day, 6x/week, 1–2 matches/week). Isometric and isokinetic strength measurements were performed during active competition period using an isokinetic dynamometer (System 3, Biodex®, ENRAF-NONIUS, New York, USA) [12, 28]. Players following a rehabilitation program in the context of a recent injury, a history of injury in the preceding 3-months or surgery in the preceding 6-months were not included in the sample. Prior to the muscle strength evaluation, body length and weight were measured and players performed a standardized warming-up of 10 min cycling following by 2×20 repetitions (50–60% 1RM) of leg extension and leg curl for m. Quadriceps and m. Hamstrings respectively on standardized Technogym® fitness equipment. Hereafter all players performed the isometric and isokinetic strength test in both legs. Throughout the strength evaluation and analyses, legs were classified into the dominant leg (defined as the preferred leg when kicking the ball) vs. non-dominant leg, through personal communication with the players.

Players characteristics

In total, 364 soccer players were included in the current analyses. All players were divided into subgroups according to their pitch position (the position in which the players played > 50% of their competitive matches): goalkeepers (GK, $n=33$), central defenders (CD, $n=72$), external defenders/wingbacks (ED, $n=54$), central midfielders (CM, $n=100$), external midfielders/wingers (EM, $n=46$) and strikers (S, $n=59$) (see Table 1 for players characteristics). All data was anonymized, ensuring confidentiality of both team and players. Players and teams were informed about the risks of the procedures and written informed consent for data collection and analysis was provided as part of the player's professional contract. The study was approved by the medical ethical committee of Hasselt University and carried out according to the Declaration of Helsinki.

Isometric strength characteristics

Maximal voluntary isometric strength of the m. Hamstrings was measured in a 45° (compared to the horizontal plane) and in a 90° knee angle for m. Quadriceps and (in order to assess the impact of the force-length relationship) [29], using the isokinetic dynamometer and following the instructions of the manufacturer manual (Biodex Medical Systems, SYSTEM 3 PRO). After familiarization, two maximal isometric knee extensions (4s) and flexions (4s), followed by a 30s rest interval, were performed. The highest isometric extension and flexion peak torques (in Nm) were selected as the maximal isometric strength. All values are presented relative to body weight (Nm/kg).

Isokinetic strength characteristics

The isokinetic strength measurement was initiated following three submaximal trial knee-extensions/flexions. Players performed 5 maximal dynamic knee-extensions/flexions at a velocity of 180°/s to assess the isokinetic strength of the knee muscles [22]. 180°/s was used in this study because this is presented in literature as the medium speed used during isokinetic measurements with good reliability (with 60°/s considered as low speed, and 300°/s as high speed isokinetic characteristics) [12, 30, 31]. Extension of the knee was initiated at a joint angle of 90° to 160°. Following each extension, the leg was actively returned to the starting position from which the next contraction was immediately initiated. Throughout the range of movement, workload was kept constant during both extension and flexion. The mean value (in Nm) of the highest 3 maximal contractions was selected as the maximal isokinetic strength. All values are presented relative to body weight (Nm/kg).

Strength variables

The conventional m. Hamstrings/m. Quadriceps (H/Q) ratio was calculated by dividing the peak strength of the m. Hamstrings by peak strength of the m. Quadriceps for both isometric (in both their angles, 45° and 90° respectively) and isokinetic measurements, and was expressed as a percentage (%). Furthermore, regression analyses were performed to investigate the potential predictive variable of age on the strength outcomes.

Statistical analysis

All data were analyzed using SPSS v.22.0 (IBM, Armonk, NY). Normality of data distribution was evaluated using the Shapiro-Wilk test. Differences between legs of all players (dominant vs. non-dominant) for all variables (isometric 45° or 90°, isokinetic 180°/s for m. Quadriceps and m. Hamstrings; H/Q ratio) were analyzed using dependent t-tests. Differences between positions (goalkeepers, central defenders, external defenders, central midfielders, external midfielders, strikers) were analyzed by a repeated measures ANOVA (leg x position). Post-hoc (Tukey) comparisons were used to identify differences between positions. Regression analyses were performed to investigate predictive variable of age on the strength outcomes per player position. For every dependent strength variable, leg (dominant vs. non-dominant), angle (45°, 90°, 180°/s) and muscle (m. Quadriceps and m.

Table 1 Player characteristics

	N	Age (years)	Weight (kg)	Length (m)	BMI
General	364	22 ± 4 (16–38)	75.9 ± 8.6 (56–124)	1.81 ± 0.07 (1.64–2.09)	23 ± 2 (19–28)
GK	33	22 ± 5 (16–33)	81.7 ± 11.9 (67–124)	1.88 ± 0.08 (1.83–2.09)	23 ± 2 (20–28)
CD	72	24 ± 5 (17–38)*	80.2 ± 8.0 (64–98)	1.85 ± 0.05 (1.73–1.96)	23 ± 2 (19–28)
ED	54	22 ± 3 (17–31)	73.5 ± 5.3 (58–89) ‡	1.79 ± 0.05 (1.69–1.91) $^{\beta}$	23 ± 2 (20–27)
CM	100	21 ± 4 (17–32)	72.0 ± 7.5 (56–92) ‡	1.78 ± 0.06 (1.65–1.93) $^{\beta}$	23 ± 2 (19–27)
EM	46	22 ± 4 (16–31)	72.4 ± 7.4 (56–85) ‡	1.77 ± 0.06 (1.64–1.88) $^{\beta}$	23 ± 2 (19–26)
S	59	23 ± 4 (16–34)	79.0 ± 6.9 (61–93)	1.83 ± 0.07 (1.70–2.02)	24 ± 2 (19–28)

Data are presented as means ± SD's and ranges (min-max values), and represent subject characteristics of the general group of players and per player position (GK, goalkeepers; CD, central defenders; ED, external defenders; CM, central midfielders; EM, external midfielders; S, strikers. *$p < 0.05$ compared to respective values of CM. ‡$p < 0.05$ compared to respective GK, CD and S values. $^{\beta}p < 0.05$ compared to respective GK, CD and S values

Hamstrings) a model was created with the independent factor age. All data are presented as means ± SD's and statistical significance was set at $p < 0.05$.

Results

Player characteristics

Table 1 shows player characteristics of all players in general and of players divided into subgroups of different playing positions. In CD, age was significantly higher compared to CM (24y ± 5 vs. 21y ± 4, $p = 0.007$). In ED (73.5 kg ± 5.3), CM (72.0 kg ± 7.5) and EM (72.4 kg ± 7.4) weight was significantly ($p < 0.000$) lower compared to respective values of GK (81.7 kg ± 11.9), CD (80.2 kg ± 8.0) and S (79.0 kg ± 6.9). Length was significantly ($p < 0.000$) lower in ED (1.79 m ± 0.05), CM (1.78 m ± 0.06) and EM (1.77 m ± 0.06) compared to respective values of GK (1.88 m ± 0.08), CD (1.85 m ± 0.05) and S (1.83 m ± 0.07). No differences were found for BMI between positions ($p > 0.05$).

Isometric strength characteristics

Isometric strength of the dominant m. Hamstrings (+6%, $p < 0.000$) and m. Quadriceps (+3%, $p = 0.006$) was significantly higher in all players compared to the non-dominant side. Furthermore, H/Q ratio in all players was significantly higher in the dominant leg (+3%, $p = 0.018$) compared to the non-dominant side (see Fig. 1A and B).

Isometric strength of m. Hamstrings and m. Quadriceps in different subgroups based on pitch positions is presented in Table 2; Fig. 1C and D, where no differences were found between positions ($p > 0.05$).

Isokinetic strength characteristics

Isokinetic strength in 180°/s of all players of the dominant m. Quadriceps was significantly lower (-1.4%, $p = 0.009$) compared to the non-dominant side, whilst strength of the dominant m. Hamstrings was significantly higher (+3%, $p < 0.000$) compared to the non-dominant side. Furthermore, H/Q ratio in 180°/s was significantly higher in the dominant leg (+5%, $p < 0.000$) compared to the non-dominant side (see Fig. 2A and B).

Isokinetic strength in 180°/s of different subgroups based on playing positions is presented in Table 3, where m. Quadriceps was significantly ($p = 0.023$) higher in S compared to CM on both the dominant (+9%, see Fig. 2C) and the non-dominant side (+4%, see Fig. 2D).

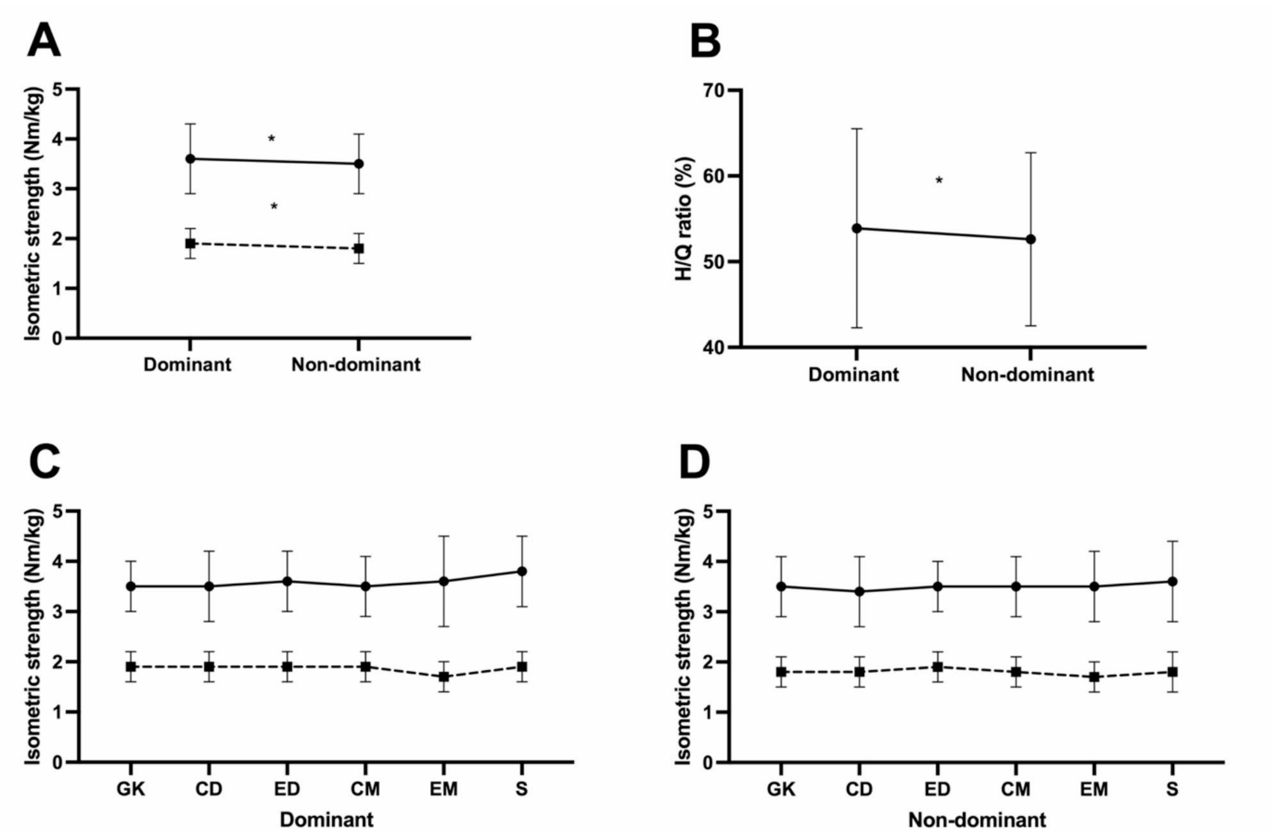

Fig. 1 Isometric strength characteristics. Data are presented as means ± SD's and represent isometric peak torque values (**A** ,in Nm/kg) and ratios (**B**, peak strength of m. Hamstrings divided by peak strength of m. Quadriceps, in %) in a 90° angle of m. Quadriceps (full line) and 45° angle of m. Hamstrings (dotted line) of the dominant and non-dominant leg, in all players (**A** & **B**) and per player positions (**C** & **D**) following 2 maximal isometric contractions (4 s)

Table 2 Isometric strength characteristics per player position

	Leg	GK ($n=33$)	CD ($n=72$)	ED ($n=54$)	CM ($n=99$)	EM ($n=46$)	S ($n=59$)
Quadriceps in 90° (Nm/kg)	D[‡]	3.47 ± 0.47 (2.4–4.2)	3.51 ± 0.68 (2.4–5.3)	3.61 ± 0.61 (2.4–5.2)	3.50 ± 0.63 (2.0–5.5)	3.56 ± 0.92 (1.9–5.9)	3.77 ± 0.72 (1.9–5.0)
	ND	3.47 ± 0.55 (2.6–4.6)	3.43 ± 0.66 (2.1–5.3)	3.53 ± 0.54 (2.4–4.5)	3.48 ± 0.55 (2.0–5.3)	3.48 ± 0.74 (2.1–5.2)	3.60 ± 0.82 (1.7–5.5)
Hamstrings in 45° (Nm/kg)	D[‡]	1.91 ± 0.23 (1.3–2.7)	1.89 ± 0.29 (1.1–2.4)	1.89 ± 0.31 (1.1–2.5)	1.88 ± 0.32 (1.1–2.9)	1.76 ± 0.32 (0.8–2.5)	1.90 ± 0.34 (1.3–2.6)
	ND	1.80 ± 0.22 (1.2–2.3)	1.79 ± 0.28 (0.9–2.5)	1.87 ± 0.33 (0.9–2.5)	1.77 ± 0.34 (1.0–3.0)	1.73 ± 0.31 (1.0–2.3)	1.84 ± 0.38 (1.2–3.0)
H/Q ratio (%)	D[‡]	57 ± 11 (38–77)	55 ± 11 (35–91)	54 ± 9 (34–85)	54 ± 12 (35–97)	52 ± 14 (30–103)	52 ± 13 (36–92)
	ND	53 ± 10 (37–74)	54 ± 13 (32–86)	54 ± 10 (28–72)	52 ± 10 (32–81)	51 ± 11 (27–72)	53 ± 13 (34–94)

Data are presented as means ± SD's and represent isometric peak torque values (in Nm/kg), ranges (min-max values) and ratios (peak strength of m.Hamstrings divided by peak strength of m. Quadriceps, in %) of m. Quadriceps and m. Hamstrings of the dominant (D) and non-dominant (ND) leg, per player positions following 2 maximal isometric contractions (4 s) in a 45° (M. Hamstrings) or 90° (m. Quadriceps) knee-angle (relative to the horizontal plane). [‡]$p<0.05$ compared to the opposite leg in all groups

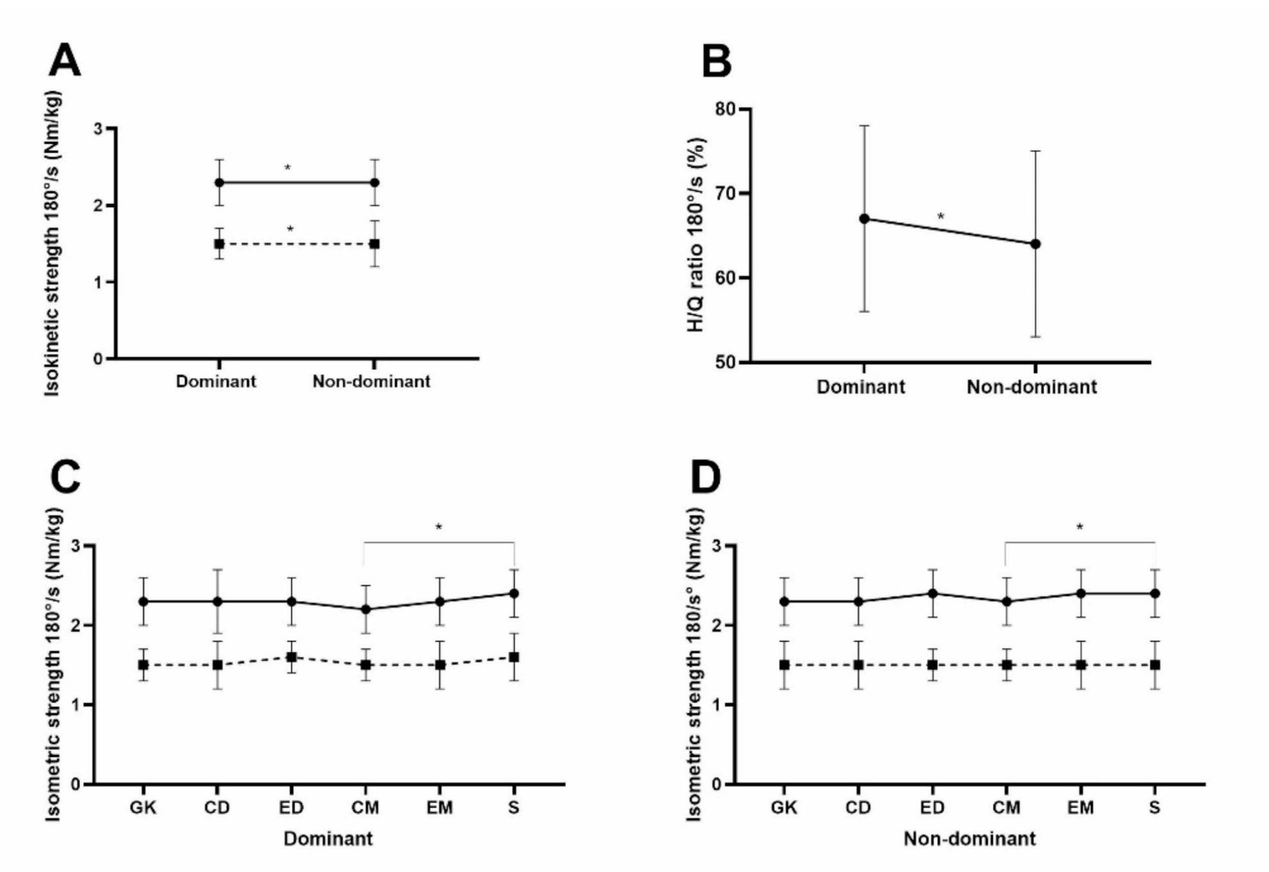

Fig. 2 Isokinetic strength characteristics in 180°/s. Data are presented as means ± SD's and represent mean peak torque values of the 3 highest maximal isokinetic contractions at 180°/s (Figure **A**, in Nm/kg) and ratios (**B**, peak strength of m. Hamstrings divided by peak strength of m. Quadriceps, in %) of m. Quadriceps (full line) and m. Hamstrings (dotted line) of the dominant and non-dominant leg, in all players (A) and per player positions (C & D) following 30 maximal isokinetic contractions. *$p<0.05$ between both mean peak torque values

No differences were found for m. Hamstrings and H/Q ratio between playing positions ($p>0.05$).

Regression analysis

For every dependent variable (all isometric and isokinetic strength outcomes as described above), a model was created with age as the independent/predictable factor, to explore the impact of age on strength measures in soccer players. No dependent strength variables were significant for the factor age ($p>0.05$).

Table 3 Isokinetic strength characteristics during 180°/sec per player position

Variables in 180°/s	Leg	GK (*n* = 33)	CD (*n* = 72)	ED (*n* = 54)	CM (*n* = 99)	EM (*n* = 46)	S (*n* = 59)
Quadriceps (Nm/kg)	D	2.27 ± 0.29 (1.6–2.8)	2.29 ± 0.36 (1.2–3.3)	2.34 ± 0.29 (1.7–3.0)	2.23 ± 0.31 (1.3–3.0)	2.31 ± 0.31 (1.8–3.0)	2.40 ± 0.33 (1.6–3.3) *
	ND‡	2.33 ± 0.31 (1.6–2.8)	2.33 ± 0.34 (1.7–3.2)	2.38 ± 0.28 (1.6–2.9)	2.26 ± 0.31 (1.5–3.1)	2.36 ± 0.27 (1.8–3.2)	2.39 ± 0.33 (1.6–3.3) *
Hamstrings (Nm/kg)	D‡	1.55 ± 0.25 (1.0–2.0)	1.54 ± 0.27 (0.6–2.0)	1.58 ± 0.19 (1.1–1.9)	1.49 ± 0.24 (0.7–2.1)	1.51 ± 0.27 (1.0–2.1)	1.58 ± 0.26 (0.9–2.1)
	ND	1.51 ± 0.26 (1.0–2.2)	1.52 ± 0.27 (0.9–2.3)	1.49 ± 0.24 (0.8–1.9)	1.46 ± 0.25 (0.9–2.0)	1.48 ± 0.28 (1.0–2.1)	1.54 ± 0.27 (0.9–2.1)
H/Q ratio (%)	D‡	69.0 ± 10.7 (46–93)	68.3 ± 12.9 (48–102)	68.1 ± 9.5 (50–93)	67.8 ± 10.9 (41–94)	65.9 ± 10.9 (42–102)	66.7 ± 10.8 (47–103)
	ND	65.1 ± 10.9 (42–88)	65.6 ± 13.3 (44–102)	64.4 ± 9.8 (37–88)	65.1 ± 11.4 (37–92)	62.6 ± 11.7 (40–92)	64.2 ± 9.1 (43–84)

Data are presented as means ± SD's and represent isokinetic peak torque values (in Nm/kg), ranges (min-max values) and ratios (peak strength of m.Hamstrings divided by peak strength of m. Quadriceps, in %) of m. Quadriceps and m. Hamstrings of the dominant (D) and non-dominant (ND) leg, per player positions following 30 isokinetic contractions at 180°/s. *$p < 0.05$ compared to respective values of CM. ‡$p < 0.05$ compared to the opposite leg in all groups

Discussion

The current study aimed to further enlarge the pool of normative data for the isometric and isokinetic strength profile of the thigh in a large sample of elite soccer players in Belgium, by pitch positions. To our knowledge, this is the first study to investigate this using a larger sample size and including both isometric and isokinetic assessments using transparent standardized and reliable protocols. Generally, we have shown that strength profiles do not differ between playing positions on the field. Furthermore, and under the conditions of the present study, age appears not to affect the strength profile of soccer players. Taken together, this is valuable information for elite soccer high performance coaches and medical staffs aiming to improve daily training efficiency and rehabilitation of their players.

In elite soccer clubs, analytic data approaches in different aspects are becoming increasingly important [32]. As such, scientific information and data on various physical performance outcomes such as muscle strength can increase the competitiveness of the team and decrease negative impacts of, for instance injured players for the club [1]. Furthermore, due to the demanding physical strain in professional soccer with an increasing number of consecutive matches, objective data and monitoring are valuable for high performance teams in order to optimally train their players and as such avoid muscle injury. Consequently, strength profiles of soccer players have been evaluated. Estradiote et al. [18] found that the isokinetic strength of the knee flexors of the dominant side were stronger compared to the opposite leg at 60°/s and 300°/s in professional Portuguese soccer players. Our data confirm these findings in a larger sample (*n* = 364 vs. *n* = 30), at 180°/s for the m. Hamstrings, as well as during isometric measurements, where the m. Hamstrings of the dominant side was stronger compared to the non-dominant side. Zabka et al. [20] attempted to develop reference values of isokinetic measurements in 60°/s and 240°/s. However, this research was conducted in a rather small sample (*n* = 39) where peak torque values were not corrected for body weight in the given research data. This makes comparison with our dataset difficult. The H: Q ratio, expressed as a percentage, of the higher velocity (240°/s) displayed in Zabka et al. [20] is very comparable to the ratios seen in the present study (around 67–69%). However, Zabka et al. did not differentiate between the dominant and non-dominant side and used an arbitrary left-right distribution, which presents a limitation compared to the present study where the subdivision dominant vs. non-dominant was made. Therefore, comparison of this data is rather difficult. To our knowledge, Sliwowski et al. [19] were the first to investigate strength characteristics in a larger sample of elite players (*n* = 111), with the subdivision into groups per playing position. These authors noted that the isokinetic strength profile varies according to playing positions on the field and therefore concluded that specific functional activity of players in individual field positions affects the isokinetic strength profile. This however is in contrast with our findings indicating only minor differences between both isometric and isokinetic strength profiles per playing position. We show that with exception of isokinetic strength in strikers compared to central midfielders (S vs. CM, +9%), no differences between playing positions are found in professional soccer players in Belgium. However, when looking more closely into the differences reported by Sliwowski et al. [19], it becomes clear that these differences are only found in the strength profile of goalkeepers compared to central defenders, external defenders and central midfielders whilst no other differences between positions were reported. Still, the difference in the strength profile of goalkeepers compared to field positions by Sliwowksi et al. [19] is not in accordance to the findings in our study. We have shown that in a larger sample of elite soccer players, the strength profile of goalkeepers is not different from other field positions. Burigo et al. [17] recently also investigated the isokinetic strength in (elite) soccer in a large sample ($n=582$). However, they focused on the relation between muscle injuries, more specific of the m. Hamstrings, and the isokinetic strength values. Because they did not report strength values (in Nm) and no subdivision into playing positions was shown, comparison with our large dataset is not possible.

We also investigated age effects on all strength outcomes per player position, by performing regression analyses for every strength parameter. Danneskiold et al. [11] already demonstrated that age affects muscle strength, with decreasing muscle strength with age. Interestingly, however, under the conditions of this study age did not seem to affect strength parameters. It was our hypothesis that younger soccer players in Belgium, at the beginning of their career, would present different (e.g. lower) strength profiles compared to players in the middle/end of their career, as this strength profile is also found in healthy non-athletes. However, it thus seems that the strength values and profile are similar to older players, and not age-dependent. These results are very interesting and valuable, as coaches can take into account this information in the analyses of their younger talents. However, these analyses remain exploratory in the current study and should be validated/reproduced in future research. The inconsistency with findings of Danneskiold et al. [11] may lie within the fact that we have investigated muscle strength in high performance soccer players with an age range of 16–38 years, whilst Danneskiold [11] included male subjects within the range of 20–79 years. Potentially, the decline in muscle strength is seen in the older years, but not during the active period of a professional soccer player. Therefore, comparison of our data of professional soccer players to the data of Danneskiold [11] of healthy subjects, with no high-performance sports background, is rather difficult. Scoz et al. [33] did investigate the impact of age in a similar population as our study, as they investigated 570 soccer players in the first or second Brazilian division. Here, they state that midfielders and goalkeepers are most affected by ageing, with a significant reduction of strength after 29 years when compared to younger player categories [33]. However, this conclusion based on the presented data of Scoz et al. [33] seems questionable, as the design of the study may not support these statements. Players in that study [33] were not followed-up throughout their professional soccer career. Therefore, comparison of strength values of different players at different ages may not provide valid results regarding the impact of age on individual strength outcomes. To conclude such hypothesis, players should be tested more regularly throughout the years and analysis should be made with individual strength outcome data throughout the years, to identify age as a strength-decreasing factor in professional soccer. Our present data, as the data of Scoz et al. [33] was not able to provide this, therefore conclusions regarding the impact of age should be made and interpreted with caution, and needs further investigation in the future.

This study provides normative values and ratios which can be used by high performance coaches/clubs in the Belgian football community to optimize the training and rehabilitation of their team, by using these normative values and ratios as objective endpoints for training and rehabilitation. As a limitation, the extrapolation to other elite soccer leagues may be rather difficult, due to the diversity of soccer leagues across the community with different and specific demands in every league. Furthermore, it could be interesting to investigate these results in relation to other, less expensive, clinical assessment (field tests) in order to expand the clinical use of these data.

Conclusion

This normative dataset shows that strength profiles of elite soccer players in the Belgian professional soccer community do not seem to differ between pitch positions on the field. Furthermore, age does not seem to influence the strength profile of Belgian players. Taken together, this is valuable objective information which can be used by high performance coaches/clubs in the Belgian football community to optimize the training and rehabilitation of their team.

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Author contributions
CK and JV analyzed all data and prepared the manuscript. BOE provided all necessary infrastructure and reviewed the manuscripts. All authors read and approved the final manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Players and teams were informed about the risks of the procedures and written informed consent for data collection and analysis was provided as part of the player's professional contract. The study was approved by the medical ethical committee of Hasselt University and carried out according to the Declaration of Helsinki.

Consent for publication
not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Al Attar WSA, Soomro N, Sinclair PJ, Pappas E, Sanders RH. Effect of Injury Prevention Programs that Include the Nordic Hamstring Exercise on Hamstring Injury Rates in Soccer players: a systematic review and Meta-analysis. Sports Med. 2017;47(5):907–16. https://doi.org/10.1007/s40279-016-0638-2.
2. Ekstrand J, Hägglund M, Waldén M. Epidemiology of muscle injuries in professional football (soccer). Am J Sports Med. 2011;39(6):1226–32. https://doi.org/10.1177/0363546510395879.
3. Hägglund M, Waldén M, Ekstrand J. Risk factors for lower extremity muscle injury in professional soccer: the UEFA Injury Study. Am J Sports Med. 2013;41(2):327–35. https://doi.org/10.1177/0363546512470634.
4. Daneshjoo A, Rahnama N, Mokhtar AH, Yusof A. Effectiveness of injury prevention programs on developing quadriceps and hamstrings strength of young male professional soccer players. J Hum Kinet. 2013;39:115–25. https://doi.org/10.2478/hukin-2013-0074.
5. Requena B, González-Badillo JJ, de Villareal ES, Ereline J, García I, Gapeyeva H, Pääsuke M. Functional performance, maximal strength, and power characteristics in isometric and dynamic actions of lower extremities in soccer players. J Strength Cond Res. 2009;23(5):1391–401. https://doi.org/10.1519/JSC.0b013e3181a4e88e.
6. Boraczyński M, Boraczyński T, Podstawski R, Wójcik Z, Gronek P. Relationships between measures of Functional and isometric lower body strength, aerobic capacity, Anaerobic Power, Sprint and Countermovement Jump performance in Professional Soccer players. J Hum Kinet. 2020;75:161–75. https://doi.org/10.2478/hukin-2020-0045. PMID: 33312304; PMCID: PMC7706664.
7. Beato M, Maroto-Izquierdo S, Turner AN, Bishop C. Implementing Strength Training Strategies for Injury Prevention in Soccer: scientific rationale and methodological recommendations. Int J Sports Physiol Perform. 2021;16(3):456–61. https://doi.org/10.1123/ijspp.2020-0862. Epub 2021 Jan 27. PMID: 33503589.
8. Baroni BM, Ruas CV, Ribeiro-Alvares JB, Pinto RS. Hamstring-to-quadriceps Torque Ratios of Professional Male Soccer players: a systematic review. J Strength Cond Res. 2020;34(1):281–93. https://doi.org/10.1519/jsc.0000000000002609.
9. Herrington L, Ghulam H, Comfort P. Quadriceps strength and functional performance after Anterior Cruciate Ligament Reconstruction in Professional Soccer players at Time of Return to Sport. J Strength Cond Res. 2021;35(3):769–75. https://doi.org/10.1519/jsc.0000000000002749.
10. van der Horst N, Backx F, Goedhart EA, Huisstede BM. Return to play after hamstring injuries in football (soccer): a worldwide Delphi procedure regarding definition, medical criteria and decision-making. Br J Sports Med. 2017;51(22):1583–91. https://doi.org/10.1136/bjsports-2016-097206.
11. Danneskiold-Samsøe B, Bartels EM, Bülow PM, Lund H, Stockmarr A, Holm CC, Wätjen I, Appleyard M, Bliddal H. Isokinetic and isometric muscle strength in a healthy population with special reference to age and gender. Acta Physiol (Oxf). 2009;197(Suppl 673):1–68. https://doi.org/10.1111/j.1748-1716.2009.02022.x.
12. Drouin JM, Valovich-mcLeod TC, Shultz SJ, Gansneder BM, Perrin DH. Reliability and validity of the Biodex system 3 pro isokinetic dynamometer velocity, torque and position measurements. Eur J Appl Physiol. 2004;91(1):22–9. https://doi.org/10.1007/s00421-003-0933-0.
13. Lum D, Haff GG, Barbosa TM. The relationship between Isometric Force-Time characteristics and dynamic performance: a systematic review. Sports (Basel). 2020;8(5):63. https://doi.org/10.3390/sports8050063. PMID: 32429176; PMCID: PMC7281606.
14. Wilson GJ, Murphy AJ. The use of isometric tests of muscular function in athletic assessment. Sports Med. 1996;22(1):19–37. https://doi.org/10.2165/00007256-199622010-00003.
15. Binder MD, Windhorst HN U. Force-length relationship. Encyclopedia of Neuroscience; 2009. p. 1615.
16. Garcia SC, Dueweke JJ, Mendias CL. Optimal joint positions for manual isometric muscle testing. J Sport Rehabil. 2016;25(4). https://doi.org/10.1123/jsr.2015-0118.
17. Burigo RL, Scoz RD, Alves BMO, da Silva RA, Melo-Silva CA, Vieira ER, Hirata RP, Amorim CF. Concentric and eccentric isokinetic hamstring injury risk among 582 professional elite soccer players: a 10-years retrospective cohort study. BMJ Open Sport Exerc Med. 2020;6(1):e000868. https://doi.org/10.1136/bmjsem-2020-000868.
18. Estradiote FR, Oliveira CL AH, et al. Isokinetic analysis in professional football players. Int Phys Med Rehab J. 2017;1(3):72–4.
19. Śliwowski R, Grygorowicz M, Hojszyk R, Jadczak Ł. The isokinetic strength profile of elite soccer players according to playing position. PLoS ONE. 2017;12(7):e0182177. https://doi.org/10.1371/journal.pone.0182177.
20. Zabka FF, Valente. Henrique Gonçalves and Pacheco, Adriana Moré. (2011). Avaliação isocinética Dos músculos extensores e flexores de joelho em jogadores de futebol profissional. Revista Brasileira De Med do Esporte, 17, 189–92.
21. Kannus P. Isokinetic evaluation of muscular performance: implications for muscle testing and rehabilitation. Int J Sports Med. 1994;15(Suppl 1):11–8. https://doi.org/10.1055/s-2007-1021104.
22. Nitschke JE. Reliability of isokinetic torque measurements: a review of the literature. Aust J Physiother. 1992;38(2):125–34. https://doi.org/10.1016/s0004-9514(14)60557-2.
23. Askling C, Karlsson J, Thorstensson A. Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. Scand J Med Sci Sports. 2003;13(4):244–50. https://doi.org/10.1034/j.1600-0838.2003.00312.x.
24. Croisier JL, Ganteaume S, Binet J, Genty M, Ferret JM. Strength imbalances and prevention of hamstring injury in professional soccer players: a prospective study. Am J Sports Med. 2008;36(8):1469–75. https://doi.org/10.1177/0363546508316764.
25. DeLang MD, Salamh PA, Farooq A, Tabben M, Whiteley R, van Dyk N, Chamari K. The dominant leg is more likely to get injured in soccer players: systematic review and meta-analysis. Biol Sport. 2021;38(3):397–435. https://doi.org/10.5114/biolsport.2021.100265. Epub 2020 Oct 28. PMID: 34475623; PMCID: PMC8329968.
26. Rosa F, Sarmento H, Duarte JP, Barrera J, Loureiro F, Vaz V, Saavedra N, Figueiredo AJ. Knee and hip agonist-antagonist relationship in male under-19 soccer players. PLoS ONE. 2022;17(4):e0266881. https://doi.org/10.1371/journal.pone.0266881. PMID: 35427407; PMCID: PMC9012372.
27. Duarte JP, Valente-Dos-Santos J, Coelho-E-Silva MJ, Malina RM, Deprez D, Philippaerts R, Lenoir M, Vaeyens R. Developmental changes in isometric strength: longitudinal study in adolescent Soccer players. Int J Sports Med. 2018;39(9):688–95. https://doi.org/10.1055/s-0044-100389. Epub 2018 Jun 20. PMID: 29925105.
28. Feiring DC, Ellenbecker TS, Derscheid GL. Test-retest reliability of the biodex isokinetic dynamometer. J Orthop Sports Phys Ther. 1990;11(7):298–300. https://doi.org/10.2519/jospt.1990.11.7.298.
29. Prietto CA, Caiozzo VJ. The in vivo force-velocity relationship of the knee flexors and extensors. Am J Sports Med. 1989;17(5):607–11. https://doi.org/10.1177/036354658901700503.
30. Fousekis K, Tsepis E, Vagenas G. Lower limb strength in professional soccer players: profile, asymmetry, and training age. J Sports Sci Med. 2010;9(3):364–73.
31. Manolopoulos E, Papadopoulos C, Kellis E. Effects of combined strength and kick coordination training on soccer kick biomechanics in amateur players. Scand J Med Sci Sports. 2006;16(2):102–10. https://doi.org/10.1111/j.1600-0838.2005.00447.x.
32. Cacho-Elizondo S, Álvarez. /07/22). Big Data in the Decision-Making Processes of Football Teams Integrating a Theoretical Framework, Applications and Reach. J Strategic Innov Sustain. 2021;15. https://doi.org/10.33423/jsis.v15i2.2887. José-Domingo Lázaro.
33. Scoz RD, Alves BMO, Burigo RL, Vieira ER, Ferreira LMA, da Silva RA, Hirata RP, Amorim CF. Strength development according with age and position: a 10-year study of 570 soccer players. BMJ Open Sport Exerc Med. 2021;7(1):e000927. https://doi.org/10.1136/bmjsem-2020-000927.

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