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# CAN PROFESSIONAL FOOTBALL PRACTICE LEAD TO MUSCLE STRENGTH IMBALANCES?

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## ABSTRACT

In this study, we compared the knee strength parameters tested in professional football players at the preparatory and competitive seasons, separated by 12 weeks. Knee extensors and flexors peak torque, hamstring to quadriceps conventional ratio (H/Qcon), and bilateral asymmetry index (AI) on the dominant and non-dominant limbs of 10 football players were evaluated in an isokinetic dynamometer. Paired t-test was used to compare all variables between the preparatory and competitive seasons. A one-sample t test was used to compare the H/Qcon and AI with theoretical means defined as 0.6 and 10%, respectively. The results showed a significant peak torque improvement in the dominant side for both knee extensors (p=0.013) and flexors (p=0.003), whereas on the non-dominant limb there was no significant difference. Regarding the H/Qcon, dominant and non-dominant sides were below 0.6 during the preparatory and competitive seasons (p<0.001). The AI was significantly lower than 10% for the knee extensors during the competitive season (p=0.001) and for the knee flexors during the preparatory season (p=0.005), without difference between the preparatory and competitive seasons for the knee extensors and flexors. These results indicate that professional football practice potentially increases interlimb strength asymmetries, therefore, lower extremity limb dominance should be considered when designing resistance training and injury prevention programs for professional football players, as well special attention should be taken regarding the strengthening of the knee flexor muscles.


**Key words:** Bilateral asymmetry. H/Q ratio. Knee extensors. Knee flexors. Torque.


## RESUMO

A prática do futebol profissional pode levar a desequilíbrios de força muscular?

Nesse estudo, comparamos os parâmetros de força do joelho testados em jogadores profissionais de futebol nas temporadas preparatória e competitiva, separados por 12 semanas. Pico de torque dos extensores e flexores do joelho, razão convencional isquiotibiais/quadríceps (I/Qcon) e índice de assimetria bilateral (IA) nos membros dominante e não dominante de 10 jogadores de futebol foram avaliados em um dinamômetro isocinético. O teste t pareado foi usado para comparar todas as variáveis entre as temporadas preparatória e competitiva. Um teste t de uma amostra foi usado para comparar a I/Qcon e o IA com médias teóricas definidas como 0,6 e 10%, respectivamente. Os resultados mostraram melhora significativa do pico de torque no lado dominante tanto para extensores de joelho (p=0,013) quanto para flexores (p=0,003), enquanto no membro não dominante não houve diferença significativa. Em relação à I/Qcon, os lados dominante e não dominante ficaram abaixo de 0,6 durante as temporadas preparatória e competitiva (p<0,001). O IA foi significativamente menor que 10% para os extensores do joelho durante a temporada competitiva (p=0,001) e para os flexores do joelho durante a temporada preparatória (p=0,005), sem diferença entre as temporadas preparatória e competitiva para os extensores e flexores do joelho. Esses resultados indicam que a prática profissional de futebol aumenta potencialmente as assimetrias de força entre os membros inferiores, portanto, a dominância dos membros inferiores deve ser considerada na elaboração de programas de treinamento de resistência e prevenção de lesões para jogadores profissionais de futebol, bem como atenção especial deve ser dada ao fortalecimento dos músculos flexores do joelho.


**Palavras-chave:** Assimetria bilateral. Razão I/Q. Extensores do joelho. Flexores do joelho. Torque.

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## INTRODUCTION

Due to the wide range of intermittent and physically demanding activities, contemporary football requires a high fitness level from its athletes.

Tasks such as acceleration and decelerations, repeated sprint ability, and explosive power of the lower limb are considered paramount to the football performance because they directly impact the athlete's ability to run, jump and swiftly change direction (Taşkin, 2008).

Considering the knee joint muscles are involved in all of these sport-specific actions, this region is likely the most affected by injuries during football practice (López-Valenciano et al., 2020).

While the knee extensors are mainly involved in running, jumping, and kicking the ball, the knee flexors stabilize the joint in direction changes, affect the stride length during running and decelerate the knee extension during the ball kicking (Ekstrand and Gillquist, 1983).

In light of this, the strength balance between knee flexors and extensors as well as a suitable symmetry between dominant and non-dominant lower limb may reduce the risk of injuries in professional football players (Cameron et al., 2003; Croisier et al., 2008; Söderman et al., 2001; Izovska et al., 2019).

Isokinetic dynamometry has been extensively used in sports science to assess muscle strength imbalances through indexes like the agonist/antagonist ratio and bilateral asymmetry (Bona et al., 2017; Gonosova et al., 2018; Magalhães et al., 2004).

Previous evidence indicate that such isokinetic parameters may provide useful information regarding the risk of injury (Croisier et al., 2008), specific knee injury (Iacono et al., 2018), and knee stability (Aagaard et al., 1998).

For instance, despite the wide range of values reported in the literature (from 0.40 to 0.90), a ratio of 0.60 between the knee flexors and extensors strength has been largely accepted as a reference for angular velocities ranging from 50 to 400°$s^{-1}$ (Aagaard et al., 1998; Nosse, 1982; Ruas et al., 2019).

Additionally, differences in measures of contralateral strength greater than 10-15% would be indicative of bilateral asymmetries and, consequently, greater risk of injuries (Croisier et al., 2008; Gleim et al., 1978).

Therefore, particularly in football, one of the key aims of the training process throughout the season is to improve or maintain the muscle strength and the strength balance between lower limbs and reciprocal muscle group ratio (Pérez-Gómez et al., 2020).

However, the specific tasks associated with football practice (e.g., cutting skills, kicking, and conducting the ball) are primarily unilateral, requiring more from the dominant member (Fousekis et al., 2010).

In this sense, the unilateral tasks involving footedness performed mainly during specific football training and matches could lead to an imbalance in the musculoskeletal function on the dominant and non-dominant sides, increasing the risk of injury.

Therefore, the purpose of the present study is to investigate whether there are differences in (i) the isokinetic peak torque of the knee extensors and flexors; (ii) the hamstring/quadriceps ratio; and (iii) the strength asymmetry of the dominant and non-dominant sides, when comparing the preparatory and competitive seasons of professional football players.

On account of the possible greater volume of specific unilateral tasks performed throughout the competitive season, we hypothesized that the strength balance between lower limbs or between groups of antagonist muscles is different between seasons.

Answering this question contributes to advancing our knowledge of the muscle strength imbalances caused by professional football practice, assisting in intervention strategies to reduce the risk of injuries.

## MATERIALS AND METHODS

### Participants

Ten professional football players of the first state division with no history of lower limb injuries in the last six months were evaluated during the preparatory (age: 21.44 ± 2.42 years, height: 1.78 ± 0.06 m, body mass: 77.45 ± 7.78 kg) and competitive (age: 21.62 ± 2.52 years, height: 1.78 ± 0.06 m, body mass: 75.94 ± 7.32 kg) seasons.

After being informed about the experimental procedures and possible risks, all subjects provided written informed consent before participating in the study.

The experimental protocol was conducted in accordance with the latest revision of the Declaration of Helsinki and was approved by the ethics committee of the University of Passo Fundo under opinion number: 108.527 and CAAE: 07894412.5.0000.5342.

**Isokinetic Dynamometry Test**

The study consisted of two measurement time points conducted at the beginning of the preparatory and at the middle of the competitive seasons, respectively.

The interval between the time points was 12 weeks and all procedures were carried out by the same investigator. The tests were performed on an isokinetic dynamometer (Biodex System 3 Pro, Biodex, Shirley, New York, USA) and, specifically, a concentric/concentric protocol was applied bilaterally to the knee extensor and flexor muscles.

Prior to the experiments, the athletes were instructed to perform a warm-up on a cycle ergometer for five minutes with the minimal load. They were then comfortably positioned on the dynamometer chair according to the equipment manufacturer's references and guidelines (Biodex, 2002).

The axis of rotation of the dynamometer was aligned with the axis of the knee joint and the lever arm of the device was fixed two centimeters above the medial malleolus.

In order to minimize compensatory movements, the trunk and the evaluated thigh were fixed with straps. Moreover, the tested limb was weighed by the equipment to avoid bias caused by gravity. During all measures, the range of motion was set as 0-90°, with 0° corresponding to full knee extension.

The participants were first instructed to perform a specific warm-up on the isokinetic dynamometer consisting of three concentric/concentric knee extension and flexion at an angular velocity of $120°s^{-1}$.

Afterwards, they were asked to perform five repetitions of maximal concentric/concentric knee extension and flexion at $60°s^{-1}$.

During the contractions, a verbal encouragement was constantly given to the athletes by the same investigator (Bona et al., 2017).

Both sides (dominant and non-dominant) were tested in a randomized order with 5 min of rest between.

**Assessing the Isokinetic Muscle Strength** Parameters

For each time point (preparatory and competitive), the hamstring to quadriceps conventional strength ratio ($H/Q_{con}$) and bilateral asymmetry index (AI) were calculated from the peak torque (i.e., the highest torque value obtained during the tasks) obtained for knee extensors and flexors. Specifically, the $H/Q_{con}$ was calculated as the ratio between the knee flexion concentric peak torque and the knee extension concentric peak torque (Aagaard et al., 1998; Osternig, 1986).

The AI was computed using the equation proposed by Coratella et al., (2018):

$$\text{AI}\ (\%) = \frac{(\text{Stronger limb}) - (\text{Weaker limb})}{(\text{Stronger limb})} \text{ x } 100$$

**Statistical analysis**

All statistical analyses were performed using a statistical software package (GraphPad Prism for Windows version 9.0).

The significance level was set at $p < 0.05$. After ensuring data normality (Shapiro-Wilk test), the paired t-test was used to compare the knee extensors peak torque, knee flexors peak torque, $H/Q_{con}$, and AI between the preparatory and competitive seasons.

The peak torque and $H/Q_{con}$ were tested separately for dominant and non-dominant sides, and the AI separately for extensors and flexors. Furthermore, the one-sample t-test was used to compare the $H/Q_{con}$ and AI with theoretical means defined as 0.6 and 10%, respectively (Ruas et al., 2015a, 2015b).

Hedges's g effect size was calculated to assess the magnitude of mean differences between the preparatory and competitive seasons measures (i.e., small: $d < 0.2$; moderate: $0.2 \leq d \geq 0.8$; large: $d > 0.8$).

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## RESULTS

### Peak torque

For the dominant side, both the knee extensors and the knee flexors peak torque significantly increased at the competitive with respect to the preparatory season for knee extensors (p=0.013; g=0.554; CI = -0.339 – 1.448) and for knee flexors (p=0.003; g=0.788; CI = -0.122 - 1.698).

Conversely, for the non-dominant lower limb, no significant differences in peak torque were observed between the preparatory and competitive seasons for both knee extensors (p=0.320; g=0.142; CI = -0.736 - 1.019) and knee flexors (p=0.617; g=0.097; CI = -0.780 - 0.974) (Table 1).

**Table 1 -** Mean and standard deviation (±) for isokinetic peak torque.

| | Isokinetic peak torque at 60°s$^{-1}$ (Nm) | | | |
|---|---|---|---|---|
| | Knee Extension | | Knee Flexion | |
| | Dominant | Non-dominant | Dominant | Non-dominant |
| Preparatory | 275.74 ± 38.94 | 294.66 ± 40.90 | 134.28 ± 17.98 | 135.36 ± 23.66 |
| Competitive | 298.8 ± 40.70<br>p = 0.013* | 301.06 ± 45.54<br>p = 0.320 | 149.97 ± 20.09<br>p = 0.003* | 137.74 ± 23.14<br>p = 0.617 |

**Legenda:** ∗ Significant difference between the preparatory and competitive seasons (p<0.05).

### Hamstring to quadriceps ratio

As shown in Figure 1, the H/Q$_{con}$ was significantly lower than the normative value (0.60; dashed line) for all conditions (p<0.001 for all cases).

Furthermore, no significant differences were detected between the preparatory and competitive seasons for both dominant (p=0.302; g = 0.356; CI = -0.528 - 1.239) and non-dominant (p=0.991; g = 0.004; CI = -0.873 - 0.880) lower limbs.

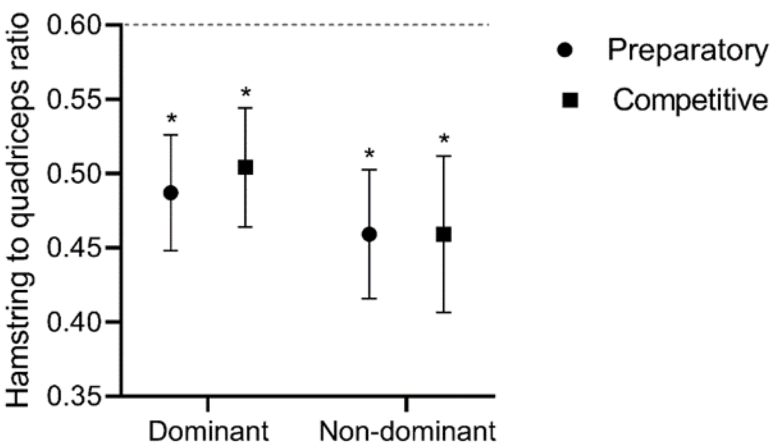


**Figure 1 -** Changes in the hamstring to quadriceps ratio for the dominant and non-dominant limbs.
**Legenda:** ∗Significant difference in relation to the theoretical mean (p<0.05; 0.60, dashed line).

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**Bilateral asymmetry index**

As shown in Figure 2, the AI was significantly lower than the normative value (10%, dashed line) for the knee extensors during the competitive season (p=0.001) and for the knee flexors during the preparatory season (p=0.005).

No significant difference was found between the preparatory and competitive seasons for both knee extensors (p=0.188; g = 0.597; CI = -0.299 - 1.492) and knee flexors (p = 0.080; g = 0.929; CI = 0.007 - 1.852).

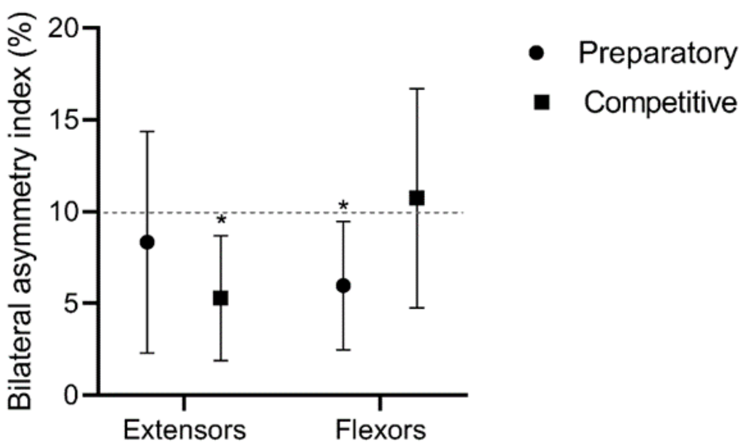


**Figure 2 -** Changes in the bilateral asymmetry index for the knee extensors and flexors.
**Legenda:** ∗Significant difference in relation to the theoretical mean ($p < 0.05$; 10%, dashed line).

**DISCUSSION**

In this study, we compared different isokinetic variables between the preparatory and competitive seasons of professional football players.

Our main results showed that (i) both knee extensors and flexors torque of dominant side increased at the competitive season with respect to the preparatory; (ii) there were no differences in the $H/Q_{con}$ and the AI between seasons.

As discussed below, these findings indicate that although the torque augmentation suggests a predominance of unilateral tasks performed with the dominant side, it was not enough to significantly change the AI.

**Changes in isokinetic knee extensors and flexors torque**

In football, several studies have examined isokinetic knee extensors and flexors torque (Bona et al., 2017; Fousekis et al., 2010; Ruas et al., 2015a, 2015b).

This measure is commonly quantified during initial phase of the preparatory period and has been widely used to assess strength imbalances (Croisier et al., 2008).

However, at the best of our knowledge, only few studies investigated isokinetic torque in more than one period throughout of the professional football season (Brow, 2020; Eniseler et al., 2012).

As showed in Table 1, our results indicate that knee extensors mean torque increased 8.36% in the dominant side and 2.17% in non-dominant side, whereas knee flexors mean torque increased 11.68% in the dominant side and 1.76% in non-dominant side.

This asymmetrical augmentation of torque may be explained by specific tasks associated with the football practice, such as kicking the ball, which is predominantly unilateral and performed with the preferred limb (Fousekis et al., 2010).

Even though this task can be performed with both lower extremities, football players presumably may produce a higher ball speed with their dominant side kicking the ball due to a better inter-segmental motion pattern and a

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transfer of velocity from the foot to the ball (Dörge et al., 2002).

Such kinematic difference between dominant and non-dominant sides could induce specific neuromuscular adaptation in the preferred lower limb when compared with the contralateral side. In contrast to our results, Eniseler and Colleagues (2012) compared the first week of football training with the last week of the season (separated by 24 weeks) and reported no differences in peak torque between these periods when the angular velocity was at $60°s^{-1}$.

These contradictory findings may be explained by the different periods in which the torque was assessed. While we evaluate at the beginning and the middle of the season, Eniseler and Colleagues (2012) compared the initial and final periods, in which the accumulated fatigue throughout the complete season possibly had a negative effect on the isokinetic peak torque at the slowest velocities.

**$H/Q_{con}$ ratio changes**

Although the isokinetic peak torque is the parameter most commonly used to assess muscle strength (Osternig, 1986), when the objective is to evaluate the knee joint strength balance, the $H/Q_{con}$ ratio seems to be preferable to the maximum torque (Baltzopoulos, Brodie, 1989).

Similar to other sports involving jumping and sprints, the quadriceps is highly requested in football, which may results in a strength imbalance with its antagonist muscle group (Ruas et al., 2015b).

Here we found $H/Q_{con}$ values significantly lower than 0.60 for both the dominant and non-dominant limbs (Figure 1), suggesting this strength imbalance occurred bilaterally.

Considering the dominant member presumably performs more football-specific tasks in relation to its contralateral, we hypothesized that a greater strength imbalance between the knee flexors and extensors would be observed on the dominant side. Interestingly, there were no significant differences in the $H/Q_{con}$ ratio, which could be explained by the similar responses between the dominant (approximate torque increase) and non-dominant (no difference) agonist/antagonist pairs.

As previously mentioned, the increase in knee flexor peak torque jointly with its antagonist group may be result of training favoring the dominant member, or the increased demand in tasks such as decelerations and changes of direction. In relation to the strength imbalances also identified in the competitive season, a possible explanation is that the training performed after the first evaluation was not efficient to improve $H/Q_{con}$ ratio.

While some studies report that strength imbalance in the H/Q ratio is a limited (Green et al., 2017) or weak (Van Dyk et al., 2016) predictive of hamstring injuries, another study indicates that the untreated strength imbalances increase the risk of injury to the hamstrings by more than 4 times compared to a normal strength profile (Croisier et al., 2008).

Intrinsic factors related to individual characteristics seem to be indeed more predictive of injury than extrinsic factors, since the player is more susceptible to exceed the mechanical limits tolerated by the musculotendinous unit.

In this context, the isokinetic parameters normalization related to the imbalances of the $H/Q_{con}$ ratio can lead to a significant reduction in the subjective intensity of athlete discomfort and to the prevention of hamstring injuries (Croisier et al., 2002).

**Bilateral AI changes**

Another main isokinetic parameter used to identify abnormalities of strength between contralateral homologous muscles is the bilateral AI.

This measure provides important information for designing resistance training and injury prevention programs (Ibis et al., 2018; Ruas et al., 2015a), as well can be used to define the return to sport after anterior cruciate ligament reconstruction (Grindem et al., 2016).

In general, isokinetic bilateral AI of knee extensors and flexors between the dominant and non-dominant limbs has been found to be at the level of 10% in football players (Carvalho and Cabri, 2007; Ruas et al., 2015a) and asymmetries above 15% may indicate a disorder in muscle function (Croisier et al., 2002; 2008).

As observed in Figure 2, the AI of knee extensors reduced in the second assessment and was significantly lower than the theoretical mean stablished as normative value. This outcome indicates an improvement in regarding the strength balance between dominant and non-dominant sides and is related to the greater increase in peak torque of the knee extensors on the dominant side.

Regarding the knee flexors, the AI got worse in the second assessment, but was not significantly higher than the theoretical mean. This divergency between AI of knee extensors and flexors is related to the peak torque observed during the preparatory season, since the peak torque of knee extensors in the dominant side improved in the second assessment and was more balanced with the contralateral side.

Even with a significant improvement only in the peak torque of dominant side for both knee extensors and flexors, this was unable to negatively affect the AI after 12 weeks. In regard, we speculate that for a longer period the AI could be impaired.

However, contrasting this argument, after 24 weeks Eniseler and Colleagues (2012) did not find differences between the first and second isokinetic assessment at 60°$s^{-1}$ for the knee extensors and flexors.

Possibly, the specific resistance training reported by the authors may have had a positive influence so that the football-specific demands would not cause an imbalance in the capacity to produce strength between the dominant and non-dominant sides.

## CONCLUSION

In conclusion, our results show that, when tested at 60°$s^{-1}$, knee extensors and flexors torque have improved only in the dominant side after 12-week professional football practice.

Adopting 10% as the reference value, this asymmetrical torque improvement was not able to negatively affect the bilateral AI. However, although we have not observed a statistical difference between seasons, the mean value in the knee flexors for the competitive season was above 10% and a large effect size was observed.

Such a result indicated that athletes got worse their knee flexors bilateral AI, since during the preparatory season the value was significantly below 10%.

This means that probably due to limb dominance, professional football practice potentially increases interlimb strength asymmetries, especially between the knee flexors.

Additionally, the $H/Q_{con}$ ratio remained below 0.60 in all conditions, indicating that only professional football practice is not enough to achieve a proper knee flexors and extensors strength balance.

Therefore, lower extremity limb dominance is a crucial variable that should be considered when designing resistance training and injury prevention programs for professional football players, as well special attention should be taken regarding the strengthening of the knee flexors.

## ACKNOWLEDGEMENTS

The authors gratefully acknowledge Dr Hélio V. Cabral (e-mail: H.daVeigaCabral@bham.ac.uk), Centre of Precision Rehabilitation for Spinal Pain (CPR Spine) - University of Birmingham, for his kind support in revising the manuscript language.

## DISCLOSURE OF INTEREST

The authors report no conflict of interest.

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Received for publication on 24/07/2022
Accepted on 26/08/2022