applied sciences

MDPI

Article

Impact of Flexibility on Vertical Jump, Balance and Speed in Amateur Football Players

Daniel Bogalho [1,2,3], Ricardo Gomes [3,4,5,*], Rui Mendes [3,4,5], Gonçalo Dias [3,4,5] and Maria António Castro [1,3,6,7]

[1] Coimbra Health School, Polytechnic Institute of Coimbra, 3046-854 Coimbra, Portugal; danielbogalho@estescoimbra.pt (D.B.); maria.castro@ipleiria.pt (M.A.C.)
[2] Sporting Clube de Portugal, 1501-806 Lisboa, Portugal
[3] Applied Research Unit (IIA)—Robocorp, Polytechnic Institute of Coimbra, 3045-093 Coimbra, Portugal; rmendes@esec.pt (R.M.); goncalodias@fcdef.uc.pt (G.D.)
[4] ESEC-UNICID-ASSERT, Polytechnic Institute of Coimbra, 3030-329 Coimbra, Portugal
[5] Research Unit for Sport and Physical Activity, University of Coimbra, 3040-248 Coimbra, Portugal
[6] CEMMPRE (UIDB/00285/2020), University of Coimbra, 3030-788 Coimbra, Portugal
[7] Escola Superior de Saúde, Instituto Politécnico de Leiria, 2411-901 Leiria, Portugal
* Correspondence: rimgomes@esec.pt

Abstract: Muscle strength, power, balance and speed assume decisive roles in football performance. This study aims to investigate whether lower limb flexibility, particularly the hip flexors and knee extensor and flexor muscles, are correlated with vertical jump performance, balance and speed in adult football players. A sample of 22 male amateur football players (age: 22.3 ± 3 years; height: 175.4 ± 7.4 cm; weight: 74.9 ± 11.6 kg; BMI: 24.2 ± 2.6 kg/m^2) were assessed for lower limb flexibility, vertical jump, balance and speed. Results indicated that vertical jump ability is moderately correlated with left knee extensors flexibility (ρ = −0.426; p = 0.048), which did not occur on the right side. There were no statistically significant correlations between vertical jump and knee flexors flexibility (ρ = 0.330; p = 0.133). In balance, the reaching distance on the right side presented a moderate and statistically significant correlation with the knee flexors flexibility (ρ = 0.411; p = 0.040), which was not observed on the left side. Velocity was not correlated with the knee extensors flexibility (right: ρ = 0.360; p = 0.100; left: ρ = 0.386; p = 0.076), or with the knee flexors flexibility (ρ = −0.173; p = 0.440). In conclusion, the influence of flexibility on vertical jump ability, balance and speed appears to exist. Further research should seek to clarify the associations between these abilities.

Keywords: football; flexibility; performance; jump; balance; speed

check for updates

Citation: Bogalho, D.; Gomes, R.; Mendes, R.; Dias, G.; Castro, M.A. Impact of Flexibility on Vertical Jump, Balance and Speed in Amateur Football Players. *Appl. Sci.* **2022**, *12*, 5425. https://doi.org/10.3390/app12115425

Academic Editor: Christian W. Dawson

Received: 16 March 2022
Accepted: 23 May 2022
Published: 27 May 2022

1. Introduction

Similar to other team sports, football requires adequate aerobic and anaerobic training, with the game including short high-intensity activities interspersed with longer low- to moderate-intensity activities [1–3]. In professional football, the average distance and duration of a sprint run are relatively short, rarely exceeding 20 m [4,5]. Despite its short duration, sprint performance is considered relevant for football performance [6].

As a result, football players must develop a high level of athleticism, which must be associated with a set of other factors, such as technical, tactical and mental skills, to achieve success [6,7]. Variables such as cardiorespiratory capacity, muscle strength, power, speed, agility, coordination and balance increasingly assume greater and decisive roles in the sports performance of athletes [6–9].

During a football match, players perform from 150 to 250 different actions, being forced to perform uni- and bilateral, repetitive and explosive movements, such as sudden acceleration and deceleration tasks, rapid changes in direction, shots and jumps in which unilateral dynamic balance is considered a fundamental component to ensure safety and precision [5,8,10]. The actions performed on the pitch vary according to the player's position [11]. Nonetheless, those basic movement patterns demand a rapid development of strength and high anaerobic power of the neuromuscular system to efficiently use the stretch-shortening cycle in ballistic movements [12–14].

Muscle strength is an important component of physical training in sport, both for performance and to prevent injuries [12]. Indeed, this is related to other components, such as speed, balance and vertical impulse. Previous studies on this topic have revealed positive correlations between lower limb muscle strength and sprint ability and balance [15]. Regarding vertical jump, its performance is not solely dependent on lower limb strength, but also on the rate at which the muscle units are able to generate force, the speed of contraction, the ability to use the stretching-shortening cycle and the degree of inter- and intramuscular coordination [16].

Flexibility is the ability to move a joint through its full range of motion (ROM) and is one of the five elements of health-related physical fitness, along with cardiorespiratory endurance, body composition, strength and muscle endurance. It is important in the ability to perform daily life activities, as well as in athletic performance, and depends on various specific variables, including muscle viscosity, joint capsule distensibility and adequate warming. In addition, the compliance, that is, the stiffness of various other tissues such as ligaments and tendons, can affect ROM [17].

Considering that flexibility training, through stretching, is a common practice in sport, it is up to strength and conditioning coaches, trainers and other professionals who work in the sports context to reflect on its usefulness and practical applicability [18]. Research on flexibility in football has focused primarily on studying its effect on the proneness to injury and the acute effects of stretching on performance, matters that are still not clear in the literature [2,3,7,19–34].

The incidence of injuries, particularly in the hamstrings, has received increasing attention in the football medicine community, as it is one of the most common injuries in professional football [35]. A systematic review of potential risk factors for hamstring injury in male players identified the reduced flexibility of this muscle group as a possible risk factor [19]. Decreased hamstring flexibility during preseason testing has also been associated with an increased risk of injury in football players from Belgium and England [20].

Conversely, other studies show that the risk of hamstrings injury was negatively correlated or not associated with flexibility [21,22]. Considering the above, there is an apparent conflict about the role of flexibility and stretching in reducing the risk of injuries in football players, and it is not clear which stretching practices are effective for this purpose. A meta-analysis that analyzed the effectiveness of exercise interventions in reducing the risk of sports injuries found no protective effect on stretching [29]. Consequently, there is no scientifically based prescription for stretching exercises and the recommendations in common practice are based primarily on unsystematic observations [2].

Most muscle injuries occur during eccentric contractions within the normal joint range of motion and some of the strongest risk factors are load management, the existence of a previous injury, fatigue and muscle imbalances. Therefore, increasing the range of motion through stretching is not expected to help reduce injury risk [23,36]. While some authors argue that the changes observed in the range of motion after a stretching program are due to anatomical or structural tissue changes, when large volumes and intensities are used for considerable periods [30,31] others mention that they are due to the participants' increased tolerance to the discomfort caused by stretching (neurophysiological effect) [25,32].

The literature is not consensual concerning stretching, and this practice seems to be falling into disuse, with its replacement by other tools, namely strength training [18,33]. In addition to the numerous systemic benefits, recently documented by Maestroni et al. [37], strength training has also been shown to be an effective strategy for gaining ROM in athletic populations, which may favor the choice of this type of intervention over stretching programs [38]. An increase in the length of the fascicle, a better agonist–antagonist coactivation (reciprocal inhibition) and an enhancement of the lengthening–shortening cycles are the main mechanisms proposed for these changes in flexibility as a result of strength training [33].

The contribution of flexibility to performance is still unclear [7,23–28]. In static stretching, for example, it is hypothesized that the increase in ROM around a joint occurs because of the maintenance of maximum amplitudes for longer periods, compared to alternative modalities (dynamic, ballistic or PNF), causing the increase in tendon elasticity and decrease in muscle viscosity, which produces a reduction in the stiffness of the musculotendinous unit and passive torque, generating greater stretching of the tissues [24]. However, studies have shown that this stretching modality can induce acute harmful effects, resulting from these neural and peripheral mechanisms, particularly from the reduction of musculotendinous stiffness, which effects will increase with stretching duration because of a decrease in muscle contractile capacities and the production of maximum muscle strength and power [24,25].

Hence, the literature shows that static stretching should be used with caution, or even avoided during warm-up, to prevent subsequent potentially deleterious effects on performance, except for specific cases such as athletes who will resort to extreme ranges (handball goalkeepers, gymnasts or ballerinas, for example) [18,24]. The inclusion of dynamic stretching exercises, on the other hand, can help in the warm-up and preparation process for the activity, given the increase in muscle temperature, when combined with aerobic exercise of submaximal intensity and activities specific to the sport in question [25,32].

Concerning recovery, the assumptions for the use of stretching are related to the reduction of DOMS (delayed onset muscle soreness). Evidence indicates that stretching does not reduce muscle pain or the presence of inflammatory muscle markers in the days following (up to 72 h) after exercise, whether applied before or after the activity [25,27,28]. Sands et al. [25] also concluded that static stretching exercises as a form of recovery do not present benefits compared to other passive modalities proposed in the literature, such as cryotherapy, contrast baths and electrical stimulation.

Flexibility is an important component of an athlete's physical capabilities, with important implications for their overall performance [7,8,12,17,39]. Although the acute effects of stretching on sports performance are well-established [23–28,34], few studies [7] analyze the impact of lower limb (LL) muscle flexibility concerning skills such as vertical jump, balance and speed in adult football players.

Given the above, this work aims to better understand these relations and find the associations between lower limb flexibility and vertical jump, balance and speed in amateur football players, to help develop new guidelines and recommendations alluding to flexibility, its training and its practical applicability and usefulness in the sports context and football in particular. The authors hypothesize that flexibility of the lower limbs would positively correlate with performance on vertical jump, balance and speed tests.

2. Materials and Methods

The study was observational and descriptive, being conducted at the RoboCorp laboratory—I2a of the Polytechnic Institute of Coimbra, after having received the approval of the institution's Ethics Committee (Approval number: 116_CEIPC2/2020). Data collection took place during the season when competitions resumed after being interrupted by COVID-19. The type and technique of sampling were, respectively, non-probabilistic and of convenience. The study's sample size was determined using the G*power software (Franz Faul, Edgar Erdfelder, Axel Buchner, Universität Kiel, Germany, version 3.1.9.6) with a power of 0.80, a correlation effect size of 0.60, and a significance level of 0.05. Therefore, a minimum of 17 individuals were needed.

2.1. Participants

The study sample included 22 adult, amateur football players (age: 22.3 $\pm$ 3 years; height: 175.4 $\pm$ 7.4 cm; weight: 74.9 $\pm$ 11.6 kg; BMI: 24.2 $\pm$ 2.6 kg/m^2), who met the following eligibility criteria:

Inclusion criteria: football players; being federated in the Portuguese Football Federation, at the time of 2020/2021; age ≥ 18 years old; male; accepting to participate in the study with an informed consent signed by the person.

Exclusion criteria: players unable to understand and/or perform data collection; players undergoing rehabilitation and/or with an injury for less than 3 months; players who tested positive for COVID-19 and/or had to change their lifestyle in the last 3 months.

2.2. Procedures

After presenting and explaining the procedures to the participants and consequently obtaining informed consent, characterization data were collected. Body weight was measured with an electronic scale (TANITA SC-330), with the participant wearing the least amount of clothing. For height measurement, shoes were removed before using a stadiometer. BMI was calculated by dividing body weight by the square of height [17]. Participants were also asked about some subjective indicators of well-being, namely the motivation for the proposed tasks, the quality of sleep the night before, the perception of fitness status and the perception of general well-being, through a scale from 0 (none) to 10 (maximum), to assess their physical and psychological availability [40].

Participants performed a 5 min low-intensity running warm-up exercise. After the warm-up, tests were administered to assess the characteristic football skills considered: vertical jump ability, balance and speed.

The vertical jump was evaluated with the countermovement jump. Participants started from an upright position, with feet shoulder-width apart, legs fully extended, and hands on hips to eliminate upper limb movement [41,42]; they were then asked to perform a quick semi-flexion of the hips and knees, followed by an explosive extension so that they immediately perform a maximum vertical jump [42]. Before the test participants were asked to perform several submaximal familiarization attempts. Jump height (cm) was recorded using the Optojump system (Microgate, Italy). Participants performed three trials with a 30 s recovery period between them. The mean value was used for subsequent analysis [12].

The Y balance test was used to assess balance, according to the protocol described by Shaffer et al. [43]. Starting in a unipedal support stance and with hands placed on hips, the participants were asked to reach the contralateral leg as far as possible in the three test directions (anterior, posteromedial and posterolateral). Each participant performed six training attempts to minimize the influence of a learning effect. The test was performed in the following order: anterior with the right lower limb (in support), anterior with the left lower limb, posteromedial with the right lower limb, posteromedial with the left lower limb, posterolateral with the right lower limb and posteromedial with the right lower limb, lateral with left lower limb [43]. Participants completed three successful testing attempts for each reach direction, with each of the lower limbs being averaged (absolute reach distance in cm). Subsequently, the normalized reach distance was calculated, in %, for each direction and side (absolute reach distance/actual length of the lower limb × 100) and, finally, the composite reach distance for each side, also in % (sum of the three normalized reach distances/three times the actual length of the lower limb × 100), with the lower limb measured from the anterosuperior iliac spine (ASIS) to the medial malleolus. Attempts were discarded and repeated if the participant failed to maintain a unilateral stance, failed to maintain range foot contact with the range indicator in the target area while the indicator is in motion (kicking the range indicator to obtain a performance), using the reach indicator for support, or failed to return the reaching foot to the starting position.

The 20 m sprint test was used to assess speed. The test was done on a tarmac floor, with two cone doors 20 m apart. Witty timing gates (Microgate, Italy) were used, and the participants always adopting the same posture: split posture, with one foot forward and one foot behind, with the starting line placed 0.3 m behind the first timing gate, as recommended by Altmann et al. [44]. Participants completed three trials, with 3 min of passive recovery between each trial [45], and the average time was considered.

Flexibility assessment of the hip flexor and knee extensor muscles, as well as the knee flexor muscles, was done with the modified Thomas test and the sit-and-reach test, respectively. Hip and knee flexion angles were measured with a goniometer, always by the same examiner [46].

The sit-and-reach test was done according to the protocol described by Ayala et al. [47], with the result being defined as the best of two attempts recorded [17]. When the participant could not reach the zero-box mark, the test score was set to 0 cm.

2.3. Statistical Analysis

The statistical analysis was made with IBM SPSS Statistics, version 27. Spearman's ρ correlation coefficient was used to verify the existence of correlations between the flexibility tests and vertical jump ability, balance and velocity tests. The degree of significance was set at $p < 0.05$.

3. Results

The sample included 22 adult (Table 1), amateur football players, all male (age: 22.3 ± 3 years; height: 175.4 ± 7.4 cm; weight: 74.9 ± 11.6 kg; BMI: 24.2 ± 2.6 kg/m^2). The individuals played football for 13.5 ± 3 years, mostly right-handed (n = 15; 68.2% vs. n = 7; 31.8%). Regarding the player position on the field, seven players were midfielders (31.8%), six were defenders (27.3%), five were forwards (22.7%) and four goalkeepers (18.2%). Table 1 shows the data regarding the characterization of the sample.

Table 1. Sample characterization data (n = 22) [a].

Age, Years	22.3 ± 3.0 (18–32)
Height, cm	175.4 ± 7.4 (159.7–189.7)
Weight, kg	74.9 ± 11.6 (50.4–95.4)
BMI, kg/m^2	24.2 ± 2.6 (19.8–29.9)
Lower Limb Real Length (ASIS-medial malleolus), cm	
Right	94.5 ± 5.7 (82.1–104.0)
Left	94.7 ± 5.8 (82.2–104.0)
Dominant Side	
Right	15 (68.2)
Left	7 (31.8)
Player Position on the Pitch	
Goalkeeper	4 (18.2)
Defender	6 (27.3)
Midfielder	7 (31.8)
Forward	5 (22.7)
Years of Football Practice, years	13.5 ± 3.0 (5–18)

[a] Data are reported as mean ± standard deviation (minimum–maximum) or frequency (percentage).

Moderate to high scores were observed in the evaluated subjective indicators of well-being, with emphasis on motivation for the proposed tasks (9.0 ± 1.2) and on the perception of general well-being (7.1 ± 1.2). In the other two constructs, that is, sleep quality of the previous night and perception of fitness status, the values showed greater variation compared to the previous ones, with the scores being 6.7 ± 1.7 and 6.1 ± 2.1, respectively (Table 2).

Table 2. Data on subjective markers of well-being [a].

Motivation for the Proposed Tasks	9.0 ± 1.2 (5–10)
Quality of Sleep the Night before	6.7 ± 1.7 (4–10)
Perception of Being in Shape	6.1 ± 2.1 (1–10)
Perception of General Well-Being	7.1 ± 1.2 (5–9)

[a] Data are reported as mean ± standard deviation (minimum–maximum).

Regarding the skills analyzed (vertical jump, balance and speed), the data are presented in Table 3. The mean vertical jump height was 32.4 ± 5.9 cm, with scores varying between 20.2 and 48.7 cm.

In the Y balance test, the mean values of absolute reach and normalized reach distances tended to be greater when the left lower limb was in support, in the anterior and posteromedial directions, and this difference was also noted after calculating the composite range distance (85.3 ± 10.3%)—which was expected since 15 of the 22 participants were right-handed and, for example, technical gestures such as passing, shooting or tackling are performed with support on the non-dominant side. The 20 m sprint performance varied between 2.94 and 3.67 s, with the average value of 3.26 s.

Table 3. Data on vertical jump height, balance and speed tests [a].

Vertical Jump, cm	32.4 ± 5.9 (20.2–48.7)
Balance	
Absolute Reach Distance, cm	
Anterior with right LL	68.5 ± 5.7 (58.3–79.5)
Anterior with left LL	69.2 ± 6.9 (57.8–82.7)
Postero-medial with right LL	77.4 ± 8.3 (60.5–88.5)
Postero-medial with left LL	78.7 ± 7.6 (60.4–92.7)
Postero-lateral with right LL	80.0 ± 6.8 (58.6–91.9)
Postero-lateral with left LL	79.7 ± 8.2 (60.6–92.3)
Normalized Reach Distance, %	
Anterior with Right LL	72.6 ± 6.7 (56.1–82.4)
Anterior with Left LL	73.3 ± 8.2 (55.6–84.9)
Postero-Medial with Right LL	82.0 ± 8.8 (58.4–91.9)
Postero-Medial with Left LL	83.2 ± 7.5 (62.5–92.8)
Postero-Lateral with Right LL	84.8 ± 7.7 (71.4–101.7)
Postero-Lateral with Left LL	84.3 ± 8.1 (58.2–94.3)
Composite Reach Distance, %	
Right side	84.9 ± 10.4 (59.8–103.4)
Left side	85.3 ± 10.3 (56.5–100.9)
20 m sprint time, s	3.26 ± 0.19 (2.94–3.67)

[a] Data are reported as mean ± standard deviation (minimum–maximum); LL: lower limb.

Regarding flexibility (Table 4), participants had slightly less flexibility on the left (4.9 ± 4.4°) than on the right (4.5 ± 3.9°) at the hip level. In turn, the knee extensor muscles presented very similar flexibility values for both lower limbs (Table 4).

Table 4. Data on flexibility tests [a].

Modified Thomas Test, deg (°)	
Right hip flexion	4.5 ± 3.9 (0–13)
Left hip flexion	4.9 ± 4.4 (0–15)
Right knee flexion	67.0 ± 10.1 (42–86)
Left knee flexion	67.5 ± 9.8 (48–85)
Sit-and-Reach Test, cm	27.2 ± 10.5 (6–44.5)

[a] Data are reported as mean ± standard deviation (minimum–maximum).

The sit-and-reach test average values (27.2 cm) are within the ACSM's Guidelines for Exercise Testing and Prescription [17] acceptable values for males between 20–29 years old. It should also be highlighted the diversity of values obtained, ranging from 6 to 44.5 cm.

The correlation coefficient did not find any strong ($0.7 \leq \rho \leq 0.89$) or very strong ($0.9 \leq \rho \leq 1.0$) correlations between the flexibility tests and vertical jump height, balance or speed tests (Table 5) and the vertical jump showed a statistically significant moderate correlation with the flexibility of the left knee extensors ($\rho = -0.426$; $p = 0.048$). On the right side, however, the correlation was not statistically significant ($\rho = -0.311$; $p = 0.160$).

Similarly, correlations between the vertical jump and the flexibility of the knee flexors were also weak and not statistically significant (ρ = 0.330; p = 0.133). In balance, the composite reach distance of the right side presented a moderate and statistically significant correlation (ρ = 0.411; p = 0.040) with the flexibility of the knee flexors, with the composite reach distance of the left side, although not diverting much from the contralateral, had no statistically significant correlation (ρ = 0.364; p = 0.096).

It should also be noted that weak correlations were recorded, but very close to moderate, between the speed with the flexibility of knee extensors (Table 5), which were also not statistically significant (right: ρ = 0.360; p = 0.100; left: ρ = 0.386; p = 0.076). Similarly, speed did not correlate with the flexibility of the knee flexors (ρ = −0.173; p = 0.440).

Table 5. Correlation coefficients between data on flexibility tests and data on vertical jump balance and speed tests [a].

	Vertical Jump	Composite Reach Distance, Right Side	Composite Reach Distance, Left Side	Speed
Modified Thomas Test				
Right hip flexion	0.097 (p = 0.667)	−0.004 (p = 0.986)	−0.026 (p = 0.908)	−0.151 (p = 0.501)
Left hip flexion	−0.152 (p = 0.498)	−0.016 (p = 0.942)	−0.035 (p = 0.878)	−0.025 (p = 0.912)
Right knee flexion	−0.311 (p = 0.160)	−0.100 (p = 0.659)	−0.202 (p = 0.366)	0.360 (p = 0.100)
Left knee flexion	−0.426 (p = 0.048)	−0.129 (p = 0.567)	−0.203 (p = 0.364)	0.386 (p = 0.076)
Sit-and-Reach Test	0.330 (p = 0.133)	0.411 (p = 0.040)	0.364 (p = 0.096)	−0.173 (p = 0.440)

[a] Correlation coefficients ρ of Spearman; $p < 0.05$.

4. Discussion

This study aimed to assess whether lower limb flexibility levels correlate with vertical jump height, balance and speed, in adult amateur football players. After data analysis, correlations were found between flexibility and vertical jump height, balance and speed, with weak to moderate strength associations. It was found that the lower the knee flexion angle and therefore the flexibility of knee extensors, the greater the vertical jump height, with statistical significance only for the left side (right: ρ = −0.311; p = 0.160; left: ρ = −0.426; p = 0.048).

Vertical jumps are frequent actions in football. Although the relationship between a bipedal test and single-limb flexibility may be questionable, this can be explained from a movement efficiency perspective. Players need to jump quick and explosively, with a short eccentric movement phase, and cannot be required for large knee stretching muscle units, generating larger muscle stiffness. A study developed by Rey et al. [7] indicated that the group of professional football players with lower knee extensors flexibility had greater muscle stiffness (r = 0.516; $p < 0.001$) compared with the most flexible group, which can facilitate the production and transmission of contractile force and energy release in relatively fast stretching–shortening activities such as jumping and sprinting. In this sense, the same authors observed that the less flexible players had better performance in all anaerobic performance tests, particularly the countermovement jump (difference between groups = 5.26%; p = 0.042), which was also noticed in the present study.

It should be noted that the knee flexors' flexibility did not show a statistically significant correlation, with vertical jump height (ρ = 0.330; p = 0.133). Although with a sample of amateur players and considering the differences this group may have when compared with top level players, these findings follow Rey et al. [7], who did not find evidence that flexibility limitations in the knee flexors of professional football players decrease the jump performance (difference between groups = 1.28%; p = 0.617). However, García-Pinillos et al. [12] observed that young semiprofessional players with greater knee flexors flexibility presented better results in all tasks studied, particularly the countermovement jump (between-group difference = 10.49%; p = 0.024).

In addition, Kirkini et al. [39] reported that the countermovement jump performance was significantly better in the group of young elite football players who showed higher levels of knee flexors flexibility ($p = 0.023$). The reasons for this variance in the results still need to be determined. However, age (adults and young people) and the competitive level of the sample (amateurs, semiprofessional, professionals and elite) may explain it.

Regarding balance, players with greater knee flexors flexibility showed greater range on the right ($\rho = 0.411$; $p = 0.040$), but not on the left side ($\rho = 0.364$, $p = 0.096$). This may be explained by the fact that these players were all right-footed, presenting greater hip flexion range of movement (fundamental to the lower limb in support, during the Y balance test) and knee extension (relevant to the reach of the lower limb), which allows them to make further reach distances.

In a 2020 study [8] that aimed to understand how the dynamic balance related to flexibility, sprint, strength and jump in young football players, it was found that some reach directions from the star excursion balance test and flexibility of the knee flexors had positive and significant correlations (anterior and anteromedial; $p < 0.05$), while others were considered negatively significant (posterior and posteromedial; $p < 0.05$). It should be noted that, according to Overmoyer et al. [48], the Y balance test can help identify flexibility deficits of the lower limbs and flexibility asymmetries in the ankle and hip regions, which points to the possible precarious relationship between balance and flexibility in the knee region, justifying this conflict of data.

The knee extensors' flexibility did not show statistically significant correlations with speed, despite the most flexible players being slower in the 20 m sprint (right: $\rho = 0.360$; $p = 0.100$; left: $\rho = 0.386$; $p = 0.076$). Similar to what was registered in the vertical jump, the greatest flexibility of this muscle group is not associated with an improvement in performance in these two skills, so a larger muscle stiffness may seem to be more advantageous. These results are also following Rey et al. [7], who did not find associations between speed and flexibility both for the knee extensors (difference between groups = 0.64%; $p = 0.462$) and knee flexors (difference between groups = 0.32%; $p = 0.890$). In the study by García-Pinillos et al. [12], the group with the highest knee flexors flexibility achieved better performance in the acceleration tests of 5 (difference between groups = 6.12%; $p = 0.003$) and 10 m (difference between groups = 4.09%; $p = 0.007$;), and in the 20 m sprint test (difference between groups = 3.29%; $p = 0.024$). The authors suggest that greater flexibility of knee flexors is a key factor for young football players in the performance of specific football skills such as the jump, sprint, agility and shot. However, further research should be done to clarify the conflicting results.

Our work shows some correlations between flexibility and jump performance, balance and speed, which adds to the body of knowledge that underlines the importance of this ability in football performance. A practical implication of this study is that flexibility training should be included in the training schedule, particularly for the knee flexors. Nonetheless, this practical implication must be taken with caution, as the literature shows conflicting results on this matter.

Some limitations of the present study should be mentioned. This being an observational study, it becomes impossible to establish causal relationships. Importantly, the sample size and the competitive level of the participants impaired the application of more robust statistical procedures, which could help to better clarify the associations between the variables analyzed, limiting, therefore, the generalization of this study's results. Additionally, it was not possible to respect a schedule that could standardize the effect of the circadian rhythms in the anaerobic performance tests. Finally, the forced interruption of competitions by COVID-19 may have caused a decrease in the physical capabilities of players, particularly amateurs, which may have led to different results.

5. Conclusions

The correlation coefficient did not find any strong correlation between the flexibility tests and vertical jump height, balance or speed tests. Moreover, the vertical jump showed a statistically significant moderate correlation with the flexibility of the left knee extensors. The weak correlations between the speed and the flexibility of knee extensors should also be noted. In contrast, the speed correlated, although very weakly, with the flexibility of the knee flexors.

Correlations were found between flexibility and vertical jump height, balance and speed, with weak to moderate strength associations. In this sense, players need to jump quick and explosively, with a short eccentric movement phase, and cannot be required for large knee stretching muscle units, generating larger muscle stiffness.

On the other hand, the knee flexors' flexibility did not show a statistically significant correlation with vertical jump height. The reasons for this variance in the results still need to be determined. As it was registered in the vertical jump, the greatest flexibility of this muscle group is not associated with an improvement in performance in these two skills, so a larger muscle stiffness may seem to be more advantageous.

In sum, the influence of flexibility on vertical jump ability, balance and speed appears to exist, despite further research being needed to better explain these associations.

Despite the limitations present in this study, the results presented add to the body of knowledge and confirm the conflicting results that the literature presents.

Author Contributions: D.B. and M.A.C. designed the research study; D.B., R.G. and M.A.C. conceived the data collection; D.B., R.G. and G.D. performed analysis and interpretation of the data; D.B., R.G., G.D., R.M. and M.A.C. performed the drafting the article and/or its critical revision. All authors contributed editorial changes in the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Mais Centro Program, Center Region Coordination Committee of the EU through the European Regional Development Fund.

Institutional Review Board Statement: The study was conducted following the Declaration of Helsinki and approved by the Ethics Committee of the Polytechnic Institute of Coimbra (Approval number: 116_CEIPC2/2020).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request by the corresponding authors.

Acknowledgments: D.B. acknowledges RoboCorp, i2A, Polytechnic Institute of Coimbra. M.A.C. acknowledges the support of the Centre for Mechanical Engineering, Materials and Processes-CEMMPRE of the University of Coimbra, which is sponsored by Fundação para a Ciência e Tecnologia (FCT) (UIDB/00285/2020, LA/P/0112/2020).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Nikolaidis, P.T.; Dellal, A.; Torres-Luque, G.; Ingebrigtsen, J. Determinants of acceleration and maximum speed phase of repeated sprint ability in soccer players: A cross-sectional study. *Sci. Sports* **2015**, *30*, e7–e16. [CrossRef]
2. Stojanovic, M.D.; Ostojic, S.M. Stretching and injury prevention in football: Current perspectives. *Res. Sports Med.* **2011**, *19*, 73–91. [CrossRef] [PubMed]
3. Hadjicharalambous, M.; Christou, M.; Apostolidis, A.; Zaras, N. High Levels of Hamstring Flexibility May Enhance Physical Fitness Performance in Elite Soccer-Players. *J. Phys. Fit. Treat. Sports* **2020**, *7*, 555720. [CrossRef]
4. Yanci, J.; Los Arcos, A.; Mendiguchia, J.; Brughelli, M. Relationships between sprinting, agility, one- and two-leg vertical and horizontal jump in soccer players. *Kinesiology* **2014**, *46*, 194–201.
5. Andrzejewski, M.; Chmura, J.; Pluta, B.; Konarski, J.M. Sprinting activities and distance covered by top level Europa league soccer players. *Int. J. Sports Sci. Coach.* **2015**, *10*, 39–50. [CrossRef]
6. Stølen, T.; Chamari, K.; Castagna, C.; Wisløff, U. Physiology of soccer: An update. *Sports Med.* **2005**, *35*, 501–536. [CrossRef]
7. Rey, E.; Padrón-Cabo, A.; Barcala-Furelos, R.; Mecías-Calvo, M. Effect of High and Low Flexibility Levels on Physical Fitness and Neuromuscular Properties in Professional Soccer Players. *Int. J. Sports Med.* **2016**, *37*, 878–883. [CrossRef]
8. Kartal, A. The relationships between dynamic balance and sprint, flexibility, strength, jump in junior soccer players. *Pedagogy Phys. Cult. Sports* **2020**, *24*, 285–289. [CrossRef]
9. Wong, D.P.; Hjelde, G.H.; Cheng, C.F.; Ngo, J.K. Use of the RSA/RCOD index to identify training priority in soccer players. *J. Strength Cond. Res.* **2015**, *29*, 2787–2793. [CrossRef]

10. López-Valenciano, A.; Ayala, F.; De Ste Croix, M.; Barbado, D.; Vera-Garcia, F.J. Different neuromuscular parameters influence dynamic balance in male and female football players. *Knee Surg. Sports Traumatol. Arthrosc.* **2019**, *27*, 962–970. [CrossRef]
11. Bush, M.D.; Archer, D.T.; Hogg, R.; Bradley, P.S. Factors influencing physical and technical variability in the english premier league. *Int. J. Sports Physiol. Perform.* **2015**, *10*, 865–872. [CrossRef]
12. García-Pinillos, F.; Ruiz-Ariza, A.; Moreno del Castillo, R.; Latorre-Román, P. Impact of limited hamstring flexibility on vertical jump, kicking speed, sprint, and agility in young football players. *J. Sports Sci.* **2015**, *33*, 1293–1297. [CrossRef]
13. Rodriguez-Fernandez, A.; Sanchez, J.; Rodriguez-Marroyo, J.A.; Villa, J.G. Effects of seven weeks of static hamstring stretching on flexibility and sprint performance in young soccer players according to their playing position. *J. Sports Med. Phys. Fit.* **2016**, *56*, 345–351.
14. García-Pinillos, F.; Martínez-Amat, A.; Hita-Contreras, F.; Martínez-López, E.J.; Latorre-Román, P.A. Effects of a contrast training program without external load on vertical jump, kicking speed, sprint, and agility of young soccer players. *J. Strength Cond. Res.* **2014**, *28*, 2452–2460. [CrossRef]
15. Muehlbauer, T.; Gollhofer, A.; Granacher, U. Associations Between Measures of Balance and Lower-Extremity Muscle Strength/Power in Healthy Individuals Across the Lifespan: A Systematic Review and Meta-Analysis. *Sports Med.* **2015**, *45*, 1671–1692. [CrossRef]
16. Paoli, A.; Bianco, A.; Palma, A.; Marcolin, G. Training the vertical jump to head the ball in soccer. *Strength Cond. J.* **2012**, *34*, 80–85. [CrossRef]
17. Riebe, D.; Ehrman, J.K.; Liguori, G.; Magal, M. *American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription*, 10th ed.; Wolters Kluwer: New York, NY, USA, 2018.
18. Noura, J. Available online: https://fisioterapia-desportiva-com-evidencia.webnode.pt/l/ate-onde-estica-o-alongamento/ (accessed on 23 January 2021).
19. van Beijsterveldt, A.M.C.; van de Port, I.G.L.; Vereijken, A.J.; Backx, F.J.G. Risk Factors for Hamstring Injuries in Male Soccer Players: A Systematic Review of Prospective Studies. *Scand. J. Med. Sci. Sports* **2013**, *23*, 253–262. [CrossRef]
20. Wollin, M.; Thorborg, K.; Pizzari, T. The acute effect of match play on hamstring strength and lower limb flexibility in elite youth football players. *Scand. J. Med. Sci. Sports* **2017**, *27*, 282–288. [CrossRef]
21. Wan, X.; Qu, F.; Garrett, W.E.; Liu, H.; Yu, B. Relationships among hamstring muscle optimal length and hamstring flexibility and strength. *J. Sport Health Sci.* **2017**, *6*, 275–282. [CrossRef]
22. Van Doormaal, M.C.M.; Van Der Horst, N.; Backx, F.J.G.; Smits, D.W.; Huisstede, B.M.A. No Relationship between Hamstring Flexibility and Hamstring Injuries in Male Amateur Soccer Players. *Am. J. Sports Med.* **2017**, *45*, 121–126. [CrossRef]
23. Thacker, S.B.; Gilchrist, J.; Stroup, D.F.; Kimsey, C.D. The Impact of Stretching on Sports Injury Risk: A Systematic Review of the Literature. *Med. Sci. Sports Exerc.* **2004**, *36*, 371–378. [CrossRef] [PubMed]
24. Opplert, J.; Babault, N. Acute Effects of Dynamic Stretching on Muscle Flexibility and Performance: An Analysis of the Current Literature. *Sport Med.* **2018**, *48*, 299–325. [CrossRef] [PubMed]
25. Sands, W.A.; McNeal, J.R.; Murray, S.R.; Ramsey, M.W.; Sato, K.; Mizuguchi, S.; Stone, M.H. Stretching and its effects on recovery: A review. *Strength Cond. J.* **2013**, *35*, 30–36. [CrossRef]
26. Behm, D.G.; Blazevich, A.J.; Kay, A.D.; McHugh, M. Acute effects of muscle stretching on physical performance, range of motion, and injury incidence in healthy active individuals: A systematic review. *Appl. Physiol. Nutr. Metab.* **2015**, *41*, 1–11. [CrossRef]
27. Herbert, R.D.; De Noronha, M.A. Stretching to prevent or reduce muscle soreness after exercise. *Cochrane Database Syst. Rev.* **2007**, *4*, CD004577. [CrossRef]
28. Torres, R.; Pinho, F.; Duarte, J.A.; Cabri, J.M.H. Effect of single bout versus repeated bouts of stretching on muscle recovery following eccentric exercise. *J. Sci. Med. Sport* **2013**, *16*, 583–588. [CrossRef]
29. Lauersen, J.B.; Bertelsen, D.M.; Andersen, L.B. The effectiveness of exercise interventions to prevent sports injuries: A systematic review and meta-analysis of randomised controlled trials. *Br. J. Sports Med.* **2014**, *48*, 871–877. [CrossRef]
30. Simpson, C.L.; Kim, B.D.H.; Bourcet, M.R.; Jones, G.R.; Jakobi, J.M. Stretch training induces unequal adaptation in muscle fascicles and thickness in medial and lateral gastrocnemii. *Scand. J. Med. Sci. Sports* **2017**, *27*, 1597–1604. [CrossRef]
31. Freitas, S.R.; Mil-Homens, P. Effect of 8-week high-intensity stretching training on biceps femoris architecture. *J. Strength Cond. Res.* **2015**, *29*, 1737–1740. [CrossRef]
32. Ben, M.; Harvey, L.A. Regular stretch does not increase muscle extensibility: A randomized controlled trial. *Scand. J. Med. Sci. Sports* **2010**, *20*, 136–144. [CrossRef]
33. Afonso, J.; Ramirez-Campillo, R.; Moscão, J.; Rocha, T.; Zacca, R.; Martins, A.; Milheiro, A.A.; Ferreira, J.; Sarmento, H.; Clemente, F.M. Strength Training versus Stretching for Improving Range of Motion: A Systematic Review and Meta-Analysis. *Healthcare* **2021**, *9*, 427. [CrossRef]
34. Turki-Belkhiria, L.; Chaouachi, A.; Turki, O.; Chtourou, H.; Chtara, M.; Chamari, K.; Amri, M.; Behm, D.G. Eight weeks of dynamic stretching during warm-ups improves jump power but not repeated or single sprint performance. *Eur. J. Sport Sci.* **2014**, *14*, 19–27. [CrossRef]
35. Ekstrand, J.; Hägglund, M.; Waldén, M. Epidemiology of muscle injuries in professional football (soccer). *Am. J. Sports Med.* **2011**, *39*, 1226–1232. [CrossRef]

36. Barreira, P.; Araújo, J.P.; Ferreira, R.; Loureiro, N. Epidemiology, Risk Factors, and Prevention. In *Injuries and Health Problems in Football*; Espregueira-Mendes, J., van Dijk, N., Neyret, P., Cohen, M., Della Villa, S., Pereira, H., Oliveira, J.M., Eds.; Springer: Berlin/Heidelberg, Germany, 2017; pp. 365–373. [CrossRef]
37. Maestroni, L.; Read, P.; Bishop, C.; Papadopoulos, K.; Suchomel, T.J.; Comfort, P.; Turner, A. The Benefits of Strength Training on Musculoskeletal System Health: Practical Applications for Interdisciplinary Care. *Sports Med.* **2020**, *50*, 1431–1450. [CrossRef]
38. Racil, G.; Jlid, M.C.; Bouzid, M.S.; Sioud, R.; Khalifa, R.; Amri, M.; Gaied, S.; Coquart, J. Effects of flexibility combined with plyometric exercises vs isolated plyometric or flexibility mode in adolescent male hurdlers. *J. Sports Med. Phys. Fit.* **2020**, *60*, 45–52. [CrossRef]
39. Kirkini, A.; Christou, M.; Apostolidis, A.; Toumpi, E.; Hadjicharalambous, M. High Level of Sit-and-Reach Flexibility Enhances Neuromuscular Explosiveness Performance in Young Elite Soccer Players. *Proceedings* **2019**, *25*, 27. [CrossRef]
40. Saw, A.E.; Main, L.C.; Gastin, P.B. Monitoring the athlete training response: Subjective self-reported measures trump commonly used objective measures: A systematic review. *Br. J. Sports Med.* **2016**, *50*, 281–291. [CrossRef]
41. Cheng, K.B.; Wang, C.H.; Chen, H.C.; Wu, C.D.; Chiu, H.T. The mechanisms that enable arm motion to enhance vertical jump performance-A simulation study. *J. Biomech.* **2008**, *41*, 1847–1854. [CrossRef]
42. Markovic, G.; Dizdar, D.; Jukic, I.; Cardinale, M. Reliability and factorial validity of squat and countermovement jump tests. *J. Strength Cond. Res.* **2004**, *18*, 551–555.
43. Shaffer, S.W.; Teyhen, D.S.; Lorenson, C.L.; Warren, R.L.; Koreerat, C.M.; Straseske, C.A.; Childs, J.D. Y-balance test: A reliability study involving multiple raters. *Mil. Med.* **2013**, *178*, 1264–1270. [CrossRef]
44. Altmann, S.; Hoffmann, M.; Kurz, G.; Neumann, R.; Woll, A.; Haertel, S. Different Starting Distances Affect 5-m Sprint Times. *J. Strength Cond. Res.* **2015**, *29*, 2361–2366. [CrossRef]
45. Yanci, J.; Calleja-Gonzalez, J.; Cámara, J.; Mejuto, G.; San-Román, J.; Los-Arcos, A. Validity and reliability of a global positioning system to assess 20 m sprint performance in soccer players. *Proc. Inst. Mech. Eng. Part. P J. Sport Eng. Technol.* **2017**, *231*, 68–71. [CrossRef]
46. Clapis, P.A.; Davis, S.M.; Davis, R.O. Reliability of inclinometer and goniometric measurements of hip extension flexibility using the modified Thomas test. *Physiother. Theory Pract.* **2008**, *24*, 135–141. [CrossRef] [PubMed]
47. Ayala, F.; Sainz de Baranda, P.; De Ste Croix, M.; Santonja, F. Reproducibility and criterion-related validity of the sit and reach test and toe touch test for estimating hamstring flexibility in recreationally active young adults. *Phys. Ther. Sport* **2012**, *13*, 219–226. [CrossRef] [PubMed]
48. Overmoyer, G.V.; Reiser, R.F. Relationships between lower- extremity flexibility, asymmetries, and the Y balance test. *J. Strength Cond. Res.* **2015**, *29*, 1240–1247. [CrossRef] [PubMed]