Original Research

A Cross-Sectional Study of Age-Related Musculoskeletal and Physiological Changes in Soccer Players

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Abstract

The purpose of this cross-sectional study was to compare specific musculoskeletal and physiological variables in soccer players differing in age. Subjects from three teams were studied: Group 1 (n = 8) was a college team, age = 20.5 ± 0.7 years; Group 2 (n = 8) was an amateur team, age = 26.4 ± 0.7 years; Group 3 (n = 8) was over-30s team, age = 35.3 ± 1.5 years. Each subject completed a series of tests measuring aerobic capacity, anaerobic power, body composition, lower-extremity strength, musculoskeletal flexibility, and balance in single-limb stance. Significant between-group differences were found for all variables, with the exception of aerobic capacity. Group 3 was significantly heavier than Group 2 and Group 1 and had significantly greater percent body fat than Group 2. Group 3 had significantly less knee extension/flexion strength, mean anaerobic power, and a longer time out of balance in single-limb stance than Group 2 and Group 1. Group 3 also had significantly less lumbar flexion and hip rotation flexibility than Group 1. Group 2 had significantly less knee extension strength than Group 1. Continued participation in competitive soccer beyond the age of 30 years was associated with an aerobic capacity comparable to younger players. However, marked knee extension and flexion weakness, decreased anaerobic power, lumbar flexion, and hip rotation tightness and balance deficits were noted in the older players.

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Introduction

Soccer is the most popular sport in the world with an estimated 22 million participants [1]. The musculoskeletal and physiological profile of the elite soccer player has been well documented [2–5]. The average age of the elite soccer player is 25 years [4–6] with most careers probably ending with the athlete less than 35 years old. However, the majority of adult soccer participants compete at a recreational nonelite level. The careers of adult soccer participants are now prolonged by the organization of leagues specifically for players over 30 years old. Information on the physiological profile of the adult nonelite soccer player is lacking. This population spans a wider age range than the elite player and therefore may not be represented by a specific physiological profile but rather one that changes with advancing years and decreasing time for practice.

The decline in soccer performance with advancing years is anecdotally attributed to the effects of aging. The aging process has been associated with decreased muscle mass [7,8], increased fat mass [9,10], decreased aerobic capacity [11,12], decreased ability to balance in single-limb stance [13], and decreased musculoskeletal flexibility [7,14,15]. Specific physiological differences between adult soccer players in different age groups have not previously been identified. The purpose of this cross-sectional study was to compare specific musculoskeletal and physiological parameters of nonelite adult soccer players differing in age.

Methods and Materials

The study population was sampled from three teams differing in age. Subjects in Group 1 were National Coilegiate Athletics Association (NCAA) division 1 (n = 6) and division 2 players (n = 2), with an age range of 19–24 years. Subjects in group 2 were selected from first (n = 4) and second team (n = 4) members of a club competing in the New York Metropolitan League, with an age range of 24–29 years. Subjects in Group 3 were members of the over-30s team ($n = 8$) from the same club as Group 2, with an age range of 32–44 years. Goalkeepers were excluded from each group. In Group 2 and Group 3, eleven members had previously played NCAA soccer, two had played amateur league division 1 in Europe, two had brief professional careers in Europe, and one had played college soccer in Europe. The mean years of competitive soccer for each group is shown in Table 1. All subjects underwent the following seven tests.

1. *Aerobic capacity* was measured on a treadmill by a metabolic measurement cart (SensorMedics 2900, Anaheim, California). The protocol involved the speed increasing 1 mph each minute from 3–6 mph, followed by an increase in elevation of 2% each minute until exhaustion. Measurements were 20-second averages. A max test was defined as no increase in Vo_2 over a one-minute period after an increase in work rate. Respiratory compensation threshold was defined as a disproportional increase in minute ventilation relative to expired CO_2.
2. *Body composition* was measured by bioelectric impedance (RJL Systems, Detroit, Michigan) using a manufacturer-supplied nongender-specific equation for estimating body density (1.1429 − 0.07122 [weight × resistance/height^2]) and the Siri equation [16] for estimating body fat. This measurement was made first on all subjects. Subjects lay for 10 minutes to adjust to room temperature before the measurement was taken.
3. *Hip strength* measurements were made with a handheld dynamometer (Nicholas MMT, Lafayette Instruments, Lafayette, Indiana). The MMT has been shown to provide torque measurements well correlated with the Cybex II isokinetic dynamometer for shoulder abduction [17]. Additionally, the measurement error was less for the MMT. For this study, the mean of two consistent readings was recorded in kilograms and converted to Nm based on the length of the individual lever arm. The lever arm for hip abduction/abduction was taken as the distance from the greater trochanter to the lateral malleolus. The lever arm for hip flexion was taken as the distance from the greater trochanter to the lateral joint line of the knee.
4. *Knee strength* measurements were made on a Cybex II isokinetic dynamometer (Cybex, Ronkonkoma, NY) at 60 degrees per second. The peak torque of three maximum efforts for each motion was recorded in Nm. Leg dominance was defined as the subject's preferred kicking leg.
5. *Musculoskeletal flexibility of the trunk and lower extremities* was assessed according to 11 different tests described previously [18]. The eleven tests were knee-to-chest, adductor, straight-leg raise, gastroc, toe out, Ober test, Thomas test, trunk rotation, Lotus test, Ely test, and toe touch (Figure 1). Each test was graded on a nominal scale of +1 = tight, 0 = normal and −1 = loose. Scores were summated to give a total flexibility score. Two tests had no loose category, and one had no tight category, allowing a range of −9 to +10 for total flexibility score.
6. A *single-limb balance* test was performed on an ankle board designed to allow movement in the frontal plane only. This instrument has been used previously to evaluate individuals with functional ankle instability [19]. Each side of the board was instrumented to detect contact with the ground. A contact switch was placed on the opposite foot to detect when the free leg was used to correct balance. The subjects attempted single-limb stance on the board for a total of five minutes for each leg. Time out of balance, as detected by

TABLE 1 Descriptive characteristics by age group

Group	Age (years)	Years Playing	Height (cm)	Weight (kg)	% Body Fat
1	20.5 ± 0.7	9.8 ± 1.2	175.8 ± 1.7	73.9 ± 1.7	13.1 ± 0.6
2	26.4 ± 0.7	15.9 ± 1.5	180.0 ± 1.7	73.9 ± 1.8	11.4 ± 1.0
3	35.3 ± 1.5	20.9 ± 1.9	179.5 ± 2.4	79.8 ± 1.9	15.6 ± 1.0
F Prob	$p < 0.0001$	$p = 0.0002$	$p = 0.2593$	$p = 0.0499$	$p = 0.0087$
Source	3 > 2 > 1	3 > 2 > 1	NS	3 > 1,2	3 > 2

Source $p < 0.05$; NS = not significant.

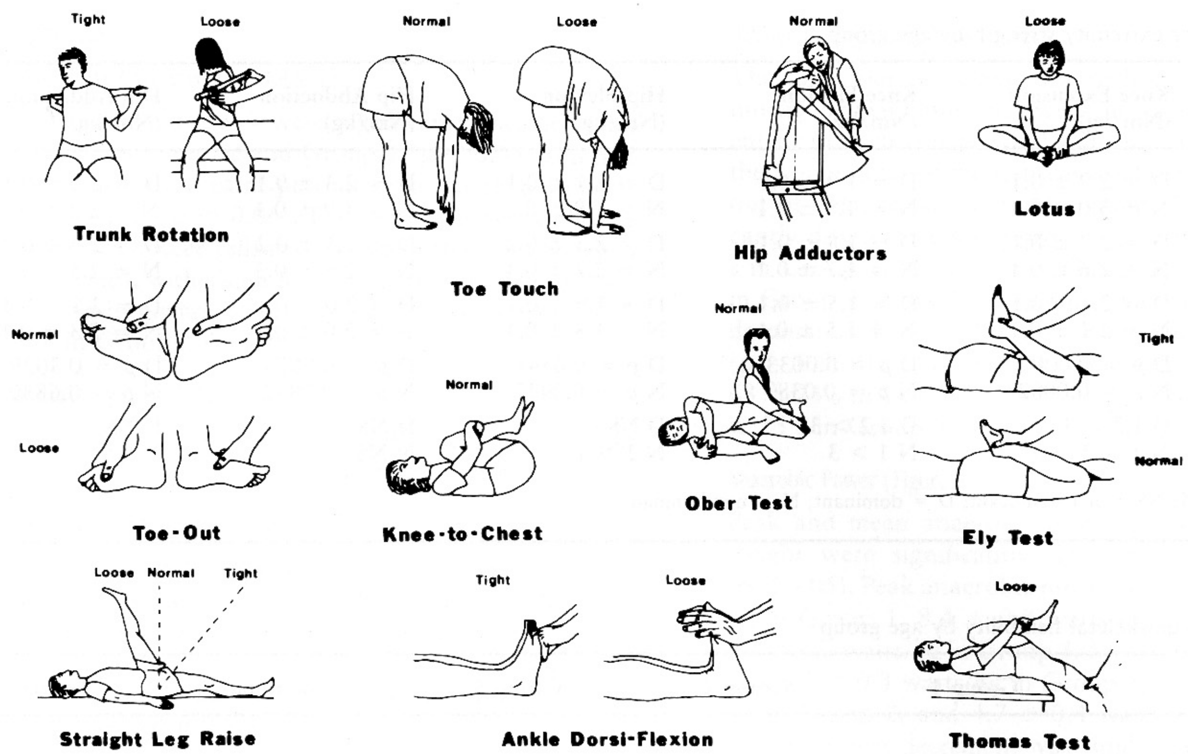

FIGURE 1 Eleven tests for assessment of musculoskeletal flexibility of the lower extremities and trunk.

board contact or opposite foot contact with the floor, was summated on a polygraph chart recorder (Grass Instruments, Quincy, Massachusetts.) Leg testing order was alternated for each subject, with a five-minute rest period between tests. A history of previous ankle injuries was obtained.

7. *Anaerobic power* was measured on a Fitron isokinetic ergometer (Cybex, Ronkonkoma, New York). Starting from rest, subjects pedalled with maximum effort at 150 rpm for 35 seconds. Work rate was recorded every five seconds. Before testing, subjects warmed up for five minutes at 90 rpm at a low work rate. The anaerobic test was performed last for all subjects.

Statistics

All data are reported as mean and standard error of the mean (SEM). A one-way analysis of variance (ANOVA) was used to test differences between the groups for each variable. The least significant difference multiple comparison test was used to indicate specific group differences. Between-group differences in individual flexibility tests were assessed by chi square. Fisher's exact test was used to indicate specific group differences in individual flexibility tests.

TABLE 2 Aerobic capacity by age group

Group	Peak V_{O_2} (mL/kg/min)	V_{O_2} at RCT (mL/kg/min)	Max HR (bpm)	Max Test (yes/no)
1	53.8 ± 2.1	44.7 ± 1.8	190 ± 1	3/5
2	54.4 ± 3.4	44.5 ± 2.6	191 ± 2	0/8
3	48.5 ± 1.5	40.1 ± 1.2	189 ± 3	4/4
F Prob	0.1771	0.1747	0.1096	Chi Square $p = 0.1077$
Source	NS	NS	NS	NS

Source $p < 0.05$; NS = not significant; RCT = respiratory compensation threshold; HR = heart rate.

TABLE 3 Lower extremity strength by age group

Group	Knee Extension (Nm/kg)	Knee Flexion (Nm/kg)	Hip Flexion (Nm/kg)	Hip Abduction (Nm/kg)	Hip Adduction (Nm/kg)
1	D = 2.9 ± 0.1 N = 3.0 ± 0.1	D = 1.9 ± 0.1 N = 1.9 ± 0.1	D = 2.1 ± 0.1 N = 1.9 ± 0.1	D = 2.3 ± 0.1 N = 1.9 ± 0.1	D = 2.3 ± 0.1 N = 2.2 ± 0.2
2	D = 2.7 ± 0.1 N = 2.6 ± 0.1	D = 1.8 ± 0.1 N = 1.7 ± 0.1	D = 2.3 ± 0.2 N = 2.2 ± 0.1	D = 2.5 ± 0.2 N = 2.5 ± 0.3	D = 2.4 ± 0.2 N = 2.5 ± 0.2
3	D = 2.1 ± 0.1 N = 2.1 ± 0.1	D = 1.5 ± 0.1 N = 1.5 ± 0.1	D = 1.9 ± 0.1 N = 1.8 ± 0.1	D = 2.0 ± 0.1 N = 2.0 ± 0.1	D = 2.1 ± 0.1 N = 2.3 ± 0.1
F Prob	D p = 0.0002 N p = 0.0002	D p = 0.0033 N p = 0.0387	D p = 0.0544 N p = 0.0417	D p = 0.0875 N p = 0.0842	D p = 0.3029 N p = 0.6839
Source	D 1,2 > 3 N 1 > 2 > 3	D 1,2 > 3 N 1 > 3	D NS N 2 > 1	D NS N NS	D NS N NS

Source $p < 0.05$; NS = not significant; D = dominant; N = nondominant.

TABLE 4 Musculoskeletal flexibility by age group

	Group 1	Group 2	Group 3	Chi Square	Source
Knee to Chest 0/+1	4/4	8/0	2/6	p = 0.008	2 < 1,3
Adductor −1/0/+1	0/8/0	2/4/2	1/3/4	p = 0.066	NS
Straight-Leg Raise −1/0/+1	1/6/1	1/6/1	1/5/2	p = 0.961	NS
Gastroc −1/0/+1	0/5/3	1/6/1	0/5/3	p = 0.514	NS
Toe Out −1/0	5/3	2/6	0/8	p = 0.022	1 < 3
Ober −1/0/+1	0/5/3	2/2/4	0/3/5	p = 0.207	NS
Thomas −1/0/+1	0/5/3	0/4/4	0/3/5	p = 0.607	NS
Trunk −1/0/+1	1/6/1	0/5/3	0/5/3	p = 0.514	NS
Lotus −1/0/+1	0/2/6	0/2/6	0/0/8	p = 0.301	NS
Ely 0/+1	2/6	5/3	3/5	p = 0.301	NS
Toe Touch −1/0/+1	1/7/0	3/3/2	1/2/5	p = 0.032	1 < 3
Total Flexibility	2.3 ± 0.9	1.9 ± 1.3	5.4 ± 0.9	(anova) p = 0.057	NS

−1 = loose, 0 = normal, +1 = tight (see Figure 1). Source $p < 0.05$. NS = not significant. The knee-to-chest and Ely tests had no loose category. The toe-out test had no tight category.

Results

Descriptive Characteristics (Table 1)

Subjects in Group 3 were significantly heavier than subjects in Group 2 and Group 1 ($p < 0.05$) and had a significantly greater percent body fat than subjects in Group 2 ($p < 0.05$). Differences in years playing organized soccer reflected the age differences between the groups, with a significantly greater number of years playing in Group 3 versus groups 2 and 1 ($p < 0.05$ and in Group 2 versus Group 1 ($p < 0.05$).

Aerobic Capacity (Table 2)

No significant between-group differences were found for peak V_{O_2}, V_{O_2} at RCT or max heart rate (HR).

Lower-Extremity Strength (Table 3)

Dominant and nondominant knee extension and flexion strength were significantly different between groups. Nondominant hip flexion strength was significantly greater in Group 2 compared with Group 1 ($p < 0.05$). Hip abduction and adduction strength was similar between the groups.

Musculoskeletal Flexibility (Table 4)

Significant between-group differences were found for knee to chest ($p < 0.01$), toe out ($p < 0.05$), and toe touch ($p < 0.05$). Total flexibility was not significantly different between groups ($p = 0.057$).

Balance in Single-Limb Stance (Figure 2)

The times out of balance for each successive minute during the five-minute test were not significantly different from each other. Total time out of balance over the five minutes of the test was used for analysis. Time out of balance on the nondominant limb was significantly different between groups ($p < 0.05$): 73 ± 13 s in Group 1, 80 ± 11 s in Group 2, and 116 ± 9 s in Group 3. A similar difference was observed on the dominant side but did not reach statistical significance ($p = 0.0591$). Dominant side time out of balance was 63 ± 11 s in Group 1, 79 ± 15 s in Group 2, and 109 ± 13 s in Group 3.

Anaerobic Power (Figure 3)

Peak and mean anaerobic power per kilogram body weight were significantly different between groups ($p < 0.05$). Peak anaerobic power was 9.6 ± 0.6 watts/kg in Group 1, 8.4 ± 0.8 watts/kg in Group 2, and 6.8 ± 0.7 watts/kg in Group 3. Mean anaerobic power was 6.7 ± 0.3 watts/kg in Group 1, 5.1 ± 0.7 watts/kg in Group 2, and 4.7 ± 0.4 watts/kg in Group 3. Percent power decrement was similar between groups (Group 1 = 57 ± 3%, Group 2 = 54 ± 4%, Group 3 = 55 ± 6%; $p > 0.05$).

Ankle Pathology (Table 5)

All but one subject reported previous ankle injuries resulting in lost playing time. The prevalence of ankle

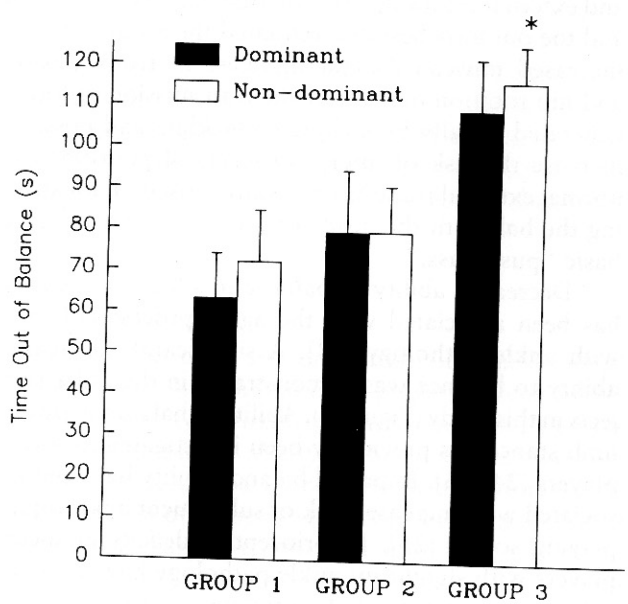

FIGURE 2 Balance in single-limb stance by age group. Dominant single-limb stance time out of balance F probability = 0.0591. Nondominant time out of balance F probability = 0.0227. *Group 3 significantly different from Group 1 and Group 2.

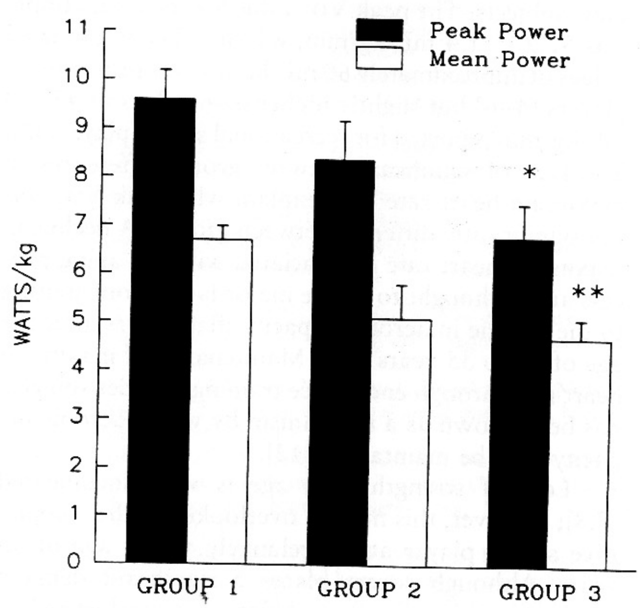

FIGURE 3 Anaerobic power by age group. Peak anaerobic power F probability = 0.0367. Mean anaerobic power F probability = 0.0197. *Group 3 significantly different from Group 1. **Group 3 significantly different from Group 1 and Group 2.

TABLE 5 Ankle injuries by age group

Group	Ankle Sprains	Bilateral Sprains	Unilateral Sprains	Recurrent Sprains
1	8	5	3	4
2	7	3	4	4
3	8	5	3	3
Total	23	13	10	10
%	96%	54%	42%	42%

injury was similar between groups with regard to numbers of unilateral, bilateral, and recurrent sprains.

Discussion

In this study, specific physiological measurements were made on nonelite soccer players from three different age levels of competition. The older players had marked knee extension and flexion weakness, lumbar flexion and hip rotation tightness, balance deficits and decreased anaerobic power relative to the younger players. As a cross-sectional study, it was impossible to specifically attribute the observed differences to the effects of aging alone. Further, the training load of the specific team was out of our control. The similarity of aerobic capacity between groups suggests that continued participation in soccer beyond the age of 30 years can maintain an aerobic capacity similar to younger players. However, it is possible that other recreational activities may have affected the aerobic capacity of these subjects. The peak $\dot{V}O_2$ value for the total sample was 52.2 ± 1.4 mL/kg/min, which is below reported values of approximately 60 mL/kg/min for professional players [4–6] but slightly higher than values of 45–50 mL/kg/min reported for recreational soccer players [2]. The lack of significant between-group differences in maximum heart rate may explain why peak $\dot{V}O_2$ was not significantly different between groups. A decline in maximum heart rate is associated with the aging process and is thought to be the major factor contributing to the decline in aerobic capacity that occurs after the age of 30 to 35 years [11]. Maintenance of maximum heart rate through endurance training in older subjects has been shown as a mechanism by which aerobic capacity may be maintained [12].

Loss of strength with age is well documented [7,8]; however, this may be overlooked in the competitive soccer player at the relatively young age of 35 years. Although soccer places a significant demand on the lower-extremity musculature, a marked reduction in knee extension and knee flexion strength was demonstrated in the older groups in this study. Of the hip musculature, only hip flexion showed significant differences between groups. The basic skill of kicking a soccer ball is an integrated action of hip, knee, and ankle musculature [20]. Maximum ball velocity for the soccer kick has been related to hip flexion and knee extension strength measurements [21]. The lower strength in Group 3 represents a significant potential for impaired performance. It is unclear why continued participation in competitive soccer does not maintain knee extension and flexion strength in players over 30 years old.

Given that soccer requires sudden bursts of energy [2], a decreased anaerobic capacity represents a significant limitation on performance. This decreased anaerobic power may in part be a reflection of knee extension and flexion strength since the test was performed on a cycle ergometer. The correlations between knee extension and flexion strength and anaerobic power were performed post hoc. Knee extension (combined dominant and nondominant) correlated significantly with peak anaerobic power ($r = 0.58$, $p < 0.01$). Knee flexion (combined dominant and nondominant) also correlated significantly with peak anaerobic ($r = 0.69$, $p < 0.01$). An anaerobic test performed on a treadmill may be a more functionally relevant test for soccer players.

Relative musculoskeletal inflexibility has been demonstrated in soccer players [2,22]. The mean flexibility score for this study sample was 3.2 ± 0.7, while it was 1.1 ± 0.1 in our normal population of 62 males [18]. The higher total flexibility score observed in Group 3 (Table 4) appeared to be a function of limited motion in lumbar flexion (knee-to-chest and toe touch) and external rotation of the hip (toe out). The toe touch and toe out tests best differentiated the groups by age. Increased musculoskeletal tightness in trunk flexion and hip rotation may affect the transmission of forces generated distally by kicking or tackling and possibly increase the risk of injury. In terms of performance, normal external rotation of the hip is essential for striking the ball with the inside of the foot to perform the basic "push pass."

Decreased ability to balance in single-limb stance has been associated with the aging process [13] and with ankle pathology [23]. A significantly decreased ability to balance was demonstrated in the older subjects in this study (Figure 2). Ability to balance in single-limb stance has previously been investigated in soccer players [24–26]. Impaired balance ability has been associated with increased risk of subsequent ankle injury playing soccer [26]. Proprioceptive deficits in soccer players with significant ankle pathology have been attributed to impairment of central mechanisms [24]. Additionally, proprioceptive training on a balance board has been shown to decrease the incidence of ankle injury in soccer [25]. All three groups in this study reported significant ankle pathology (Table 5). Although the rates of reported recurrent ankle sprains were similar between groups, it is possible that continued participation in soccer on a previously injured ankle futher disrupts the proprioceptive function. The loss of balance ability associated with aging has been identified at ages greater than 70 years [13]. The subjects tested in this study spanned a relatively narrow age range (19 to 44 years). However, a demanding balance test such as that used here has not previously been used to look at aging effects on balance. It is possible that the increased time out of balance is in part a function of aging-impaired afferent proprioceptive feedback. Another possible explanation for the loss of balance ability in the older soccer players is an impairment of vestibular function due to the cumulative effects of heading a soccer ball over 20 years of competitive play. It has been suggested that repeated mild traumas to the head associated with heading a soccer ball may cause some permanent neuronal brain damage [27]. A degree of permanent organic brain damage has been shown in former soccer players [28]. An atraumatic decrease in vestibular function is also a possibility.

The ankle has been identified as the most common site of injury in soccer [22,29–31]. Of the 24 subjects in this study, 23 reported previous ankle sprains. Ankle pathology appears to have affected the balance ability of this sample of soccer players as a whole. Mean time out of balance for the total population was 84 ± 8 s on the dominant limb and 89 ± 7 s on the nondominant limb. A control group of males ($n = 11$) without previous ankle pathology and with a mean age of 28.6 ± 2.5 years had previously been tested in our laboratory (unpublished data). For this group, mean time out of balance was 56 ± 14 s on the right limb and 56 ± 15 on the left limb. These normal values are lower than the values of each of the three groups of soccer players, suggesting that soccer participation or ankle pathology associated with soccer affects balance in single-limb stance.

Conclusion

Based on this cross-sectional study of nonelite soccer players, we conclude that older players have decreased lower-extremity strength, increased trunk and hip tightness, and impaired ability to balance and anaerobic power. Aerobic capacity appears to be maintained by continuation of competitive soccer. Longitudinal studies are necessary to confirm these findings.

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