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Review

Recreational football as a health promoting activity: a topical review

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The present review addresses the physiological demands during recreational football training and the effects on central health variables that influence the risk of life-style diseases of young and middle-aged men. Recent studies have established that recreational football, carried out as small-sided games can be characterized as having a high aerobic component with mean heart rates of 80–85% of maximum heart rate, which is similar to values observed for elite football players. In addition, the training includes multiple high-speed runs, sprints, turns, jumps and tackles, which provide a high impact on muscles and bones. Recreational football training in untrained men results in marked improvements in maximum aerobic power, blood pressure, muscle capillarization and intermittent exercise performance, and those effects are similar to interval training and more pronounced than moderate-intensity continuous running and strength training. Further, recreational football training enhances fat oxidation during exercise and results in a higher fat loss than interval training and strength training, and results in marked muscle hypertrophy and elevates bone mass, more than interval and continuous running. Taken together, recreational football appears to effectively stimulate musculoskeletal, metabolic and cardiovascular adaptations of importance for health and thereby reduces the risk of developing life-style diseases.

Poor physiological fitness arising as a consequence of a physical inactive lifestyle is a major contributor to the increasing prevalence of cardiovascular diseases, type 2 diabetes and musculo-skeletal disorders, and metabolic-related risk factors have become a large and expanding health problem in modern society (Lee & Skerrett, 2001; Mokdad et al., 2004; Hu et al., 2005). Thus, epidemiological studies and comprehensive meta-analyses of controlled randomized training studies have provided evidence that factors such as poor cardiorespiratory fitness, adiposity, insulin resistance and arteriosclerosis are independent threats to health and it is well established that exercise training may lower the risk for several cardiovascular and metabolic diseases (Halbert et al., 1997; Klarlund & Saltin, 2006; Jeon et al., 2007). Most studies looking at the effect of physical activities on health have focused on the cardiovascular and metabolic effect of aerobic exercise training such as walking, jogging, running and cycling (Klarlund & Saltin, 2006, Cornelissen & Fagard, 2005; Kiens et al., 2007; Nybo et al., 2009). There has also been some interest in effects of strength training focusing on the risk of falls and fractures related to changes in bone strength and muscle function as well as the relationship between muscle mass and qualitative myofibrillar adaptations and insulin sensitivity (Tresierras & Balady, 2009). In addition, in the last decade, the effect of concurrent aerobic and strength training has also been examined (Arthur et al., 2007; Karavirta et al., 2009). However, few studies have investigated the health effects of regular participation in a variety of sports and physical activities, which involves aerobic high-intensity training and anaerobic training, including sprints and specific actions with a high impact on muscles and bone, such as football, team handball, basketball and ice-hockey (Saltin et al., 1979; Krustrup et al., 2007, 2009a, b). The present review will deal with the health and performance aspects related to regular participation in football training and compare the effect with other types of training.

Football is a popular sport traditionally played as 11 against 11 (11 vs 11), but it is also conducted as small-sided games, such as 3 against 3 (3 vs 3), 4 vs 4, 5 vs 5 and 7 vs 7 (Hoff et al., 2002; Impellizzeri et al., 2006; Folland & Williams, 2007; Jones & Drust, 2007; Kelly & Drust, 2008). It has been established that the aerobic demands in recreational football are roughly similar to those in elite football training with periods of near-maximal heart rate values (Krustrup et al., 2007, 2009a, b). It has furthermore been shown that the activity profile during small-sided games is

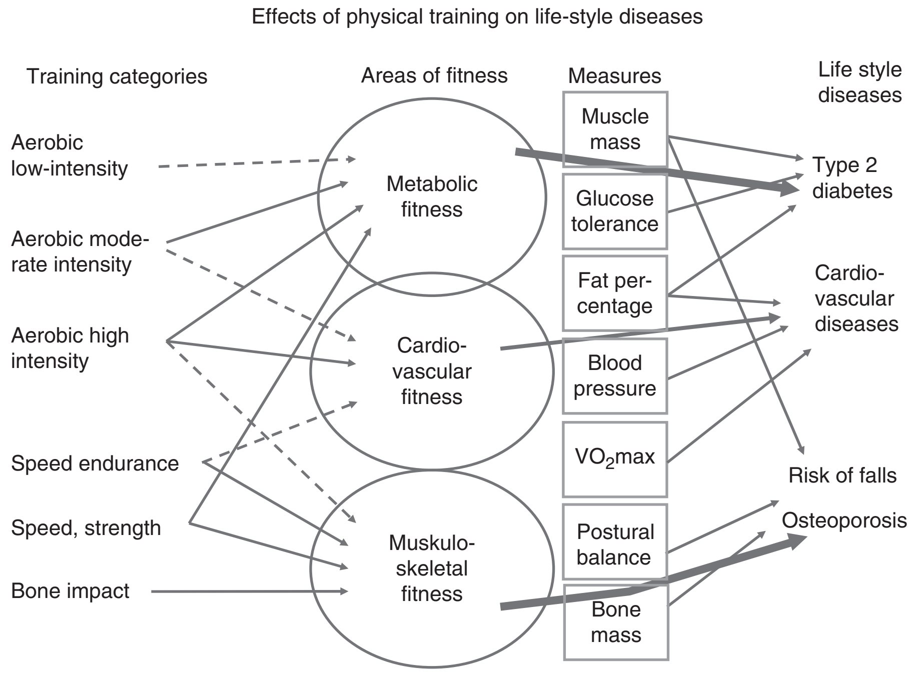

Fig. 1. Overview of the impact of different types of training on various fitness capacities and their relationship to the risk of certain life-style diseases. Full lines denote comprehensive effects and/or well-known relationships. Dotted lines denote sub-optimal yet positive effects.

highly intermittent, with multiple turns, jumps and sprints, which provide a high impact on muscles and bones (Rampinini et al., 2007b; Coutts et al., 2009; Krustrup et al., 2009a, b; Pedersen et al., 2009). On the other hand, football training and game play are also characterized by long periods of standing or walking, which is considered to have minimal or no influence on physical fitness. On this basis, it appears highly relevant to examine how effectively regular football training may affect cardiovascular and musculoskeletal factors of importance for health and physical performance.

Figure 1 provides a model of the highly complex relationship between the physical loading during physical activity, the effect on metabolic, cardiovascular and metabolic fitness, the changes in measurable health variable such as muscle mass, glucose tolerance, fat percentage, blood pressure, maximal oxygen uptake, balance and bone mass and ultimately the relationship between the three areas of fitness and the risk of lifestyle diseases. The combination of different types of exercise may be important for stimulating the various areas of fitness that are of importance for health (see Fig. 1).

The aim of the present review is to describe the effects of regular football training on cardiorespiratory capacity, metabolic fitness as well as muscle and bone strength, and compare these effects with those of isolated strength, endurance and interval training. As discussed below, the combined usage of a large number of different training components in football training, i.e. sprinting, acceleration, side cutting, rapid decelerations, maximal jumping, rapid foot strike patterns, etc appears to evoke significant adaptive changes in a number of physiological systems in the body, altogether resulting in improved cardiovascular function, enhanced bone mineralization, elevated maximal muscle force output and postural balance as well as altered fat and glucose metabolism.

The effect of recreational football training on systemic blood pressure and muscle capillaries

Twelve weeks of regular recreational football training of untrained males two to three times a week for 1 h lead to a lowered resting systolic and diastolic blood pressure of 8 and 5 mmHg, respectively (Krustrup et al., 2009a), which is similar to what has been observed after a period of endurance training of the same duration and volume (Krustrup et al., 2009a). However, not all endurance and intermittent training studies have shown a positive effect on blood pressure and often the effect is less than observed in the football training study (Table 1). In a meta-analysis including healthy sedentary normotensive or hypertensive adults with an intervention duration of at least 4 weeks involving 72 trials, 105 study groups and 3936 participants, Cornelissen & Fagard (2005) found that training induced significant net reductions in both resting systolic and diastolic blood pressure of about 3 mmHg. The lowering of blood

Table 1. Effects of short-term training for untrained subjects on blood pressure and cholesterol

Studies	Year	Training duration (weeks)	Training-program: intensity (%) frequency (per week), duration of session (min)	BPsys (rest)	BPdia (rest)	CHOLtot (rest)	HDL (rest)	LDL (rest)	Total training duration (h)	Remarks
Aerobic training										
Krustrup et al. (Football)	2009a	12	82% HR_{max}, 2–3 per week, 50 min	6%↓*	6%↓*	5%↓	8%↑	15%↓*	30	
Krustrup et al. (Cont Run)	2009a	12	82% HR_{max}, 2–3 per week, 50 min	6%↓*	6%↓*	7%↓	8%↑	4%↓	30	
Van Hoof et al.	1989	16	?, 3 per week,?	3%↓	6%↓*	–	–	–	–	
Jennings et al.	1986	4	65% (W_{max}), 3 per week, 30 min	10%↓*	7%↓*	3%↓	5%↓	–	6	
Stein et al. (low intensity)	1990	12	65% HR_{max}, 3 per week, 30 min	–	–	3%↓	3%↓	1%↓	18	
Stein et al. (moderate intensity)	1990	12	75% HR_{max}, 3 per week, 30 min	–	–	5%↓	20%↑*	11%↓*	18	
Duncan et al.	1985	16	70–80% HR_{max}, 3 per week, 45 min	9%↓*	8%↓*	–	–	–	36	
Bonanno et al.	1974	12	70–85% HR_{max}, 3 per week, 35 min	2%↑	7%↓*	13%↓*		–	21	VO_{2max} 6%↑*
Ross et al.	2000	12	77% HR_{max}, 7 per week, 700 kcal	4%↓	7%↓	–	–	–		VO_{2max} 22%↑*
Schjerve et al. (moderate intensity)	2008	12	60–70% HR_{max}, 3 per week, 47 min	–	6%↓*	–	–	4%↓	28	
Kim et al. (low intensity)	2001	24	50% VO_{2max}, 3 per week, 1 hour	–	–	0%↓	↔	3%↑	72	VO_{2max} 8%↑*
Donovan & Brooks (low intensity)	2005	24	60% VO_{2max}, 3 per week, 1200 kcal/week	–	–	3%↓	7%↑	5%↓	–	VO_{2max} 16%↑*
High-intensity training										
Nybo et al.	2010	12	$>$ 90% HR_{max}, 3 per week, 5 × 2 min	6%↓*	1%↓	2%↓	↔	3%↓	6	
Stein et al.	1990	12	85% HR_{max}, 3 per week, 30 min	–	–	0% ↔	13%↑*	2%↑	18	
Schjerve et al.	2008	12	85–95% HR_{max}, 3 per week, 4 × 4 min	–	10%↓*	–	–	7%↓*	10	
Kim et al.	2001	24	85% VO_{2max}, 3 per week, 1 hour	–	–	2%↑	2%↑	4%↑	72	VO_{2max} 8%↑*
Donovan & Brooks, 1983	2005	24	80% VO_{2max}, 3 per week, 1200 kcal/week	–	–	9%↓*	1%↓	13%↓*	–	VO_{2max} 22%↑*
Strength training										
Nybo et al. (strength)	2010	12	14 → 8 RM, 2 per week, 50 min	6%↓	9%↓	10%↑	↔	12%↓	20	
Cortez-Cooper et al.	2008	13	70% 1RM, 3 per week, 35 min	↔	3%↓	↔	7%↑	3%↓	23	VO_{2max} 2%↓
Kawano et al.	2006	16	50% 1RM, 3 per week, 45 min	3%↓	7%↓*	–	–	–	36	
Miyachi et al.	2004	16	80% 1RM, 3 per week, 45 min	↔	4%↓	–	–	–	36	
Schjerve et al. (strength)	2008	12	90% 1RM, 3 per week,?	–	2%↓	–	–	8%↓*	–	
Kokkinos et al. (low rep . hi res)	1988	10	4–5 RM, 3 per week,?	–	–	8%↑	2%↓	10%↑	–	VO_{2max} 6%↑
Kokkinos et al. (hi rep . low res)	1988	10	14–16 RM, 3 per week,?	–	–	10%↓	5%↑	5%↓	–	VO_{2max} 4%↑
Hurley et al.	1988	16	10–20 RM, 3–4 per week,?	↔	6%↓*	↔	13%↑*	5%↓*	–	VO_{2max} 5%↑

BPsys, systolic blood pressure; BPdia, diastolic blood pressure; CHOLtot, total plasma cholesterol; HDL, High density lipoprotein; LDL, low density lipoprotein.

pressure for football players was also larger than with a comparable period of strength training in a group of sedentary people (Table 1). The improvements for the football players were of a magnitude that has been suggested to have significant health beneficial effects (Pedersen & Saltin, 2006). Thus, based on 61 prospective studies, the risk of cardiovascular death was found to decrease linearly with the decreasing blood pressure until a systolic pressure of 115 mmHg and a diastolic pressure of 75 mmHg (Cornelissen & Fagard, 2005), which correspond to the levels that were reached after 12 weeks of recreational football training (Krustrup et al., 2009a; Table 1). It was also observed that the reduction of resting blood pressure was more pronounced in the seven subjects with the highest initial blood pressure (reduction in MAP of 8 mmHg, Krustrup et al., 2009a), which is in accordance with studies investigating the effects of aerobic training (Pescatello et al., 2004; Cornelissen & Fagard, 2005). Thus, Cornelissen and Fagard included 30 hypertensive study groups and found a reduction in systolic and diastolic pressure of 6.9 and 4.9 mmHg, respectively, compared with 1.9 and 1.6 mmHg, respectively, in the normotensive study groups.

The lowered blood pressure in the sedentary males taking part in regular football training was associated with a reduction in resting heart rate, which may reflect a lowering of the sympathetic outflow, and thereby reduced systemic vascular resistance (Krustrup et al., 2009a). In addition, muscle capillarization (expressed as number of capillaries per fiber) was considerably elevated in the football group (23%) after the 12 weeks of training (Krustrup et al., 2009a, b). It is possible that other vascular structural adaptations may have occurred (Laughlin et al., 1996). These include vascular remodeling, i.e. increased length, cross-sectional area and/or diameter of already existing arteries and veins, as observed in endurance trained rats (Lash & Bohlen, 1992). Furthermore, a lowered precapillary vascular resistance of hindquarters isolated from trained normotensive (Sexton et al., 1988; Edwards & Diana, 1978) and spontaneously hypertensive rats have been demonstrated (Sexton & Laughin, 1994). Together, the elevated number of capillaries and these other possible training-induced alterations in the vascular structure may have lowered the peripheral resistance and in part explain the reduced resting blood pressure.

The subjects carrying out the football training program had a decrease in heart rate during submaximal continuous running, which is a common finding after a period of endurance training of untrained subjects (Beneke & Hutler, 2005; Table 3). This may be related to an increased blood volume and an elevated ventricular volume, which have been observed to occur in a number of studies of endurance training (Goodman et al., 2005). Interestingly, the football group had a lowering of heart rate also during intermittent exercise, which was not observed in a group performing endurance training with the same average heart rate and duration (Krustrup et al., 2009b). These findings suggest that the type of training is influencing the cardiovascular responses to various types of exercise, and that the adaptations are not only occurring in central factors but are also affected by peripheral variables.

The effect of recreational football training on VO_{2max}

In the study of sedentary males taking part in recreational football training for 12 weeks, the increase in VO_{2max} was 13%, which is similar to observations in studies using continuous training with a similar amount of total training hours and investigations with high-intensity intermittent training with less total amount of training (Fig. 2, Table 3). VO_{2max} continued, in contrast to a comparable running group, to increase after the first 4 weeks of training indicating that the football group maintained the stimuli for cardiovascular and respiratory adaptations throughout the entire training period. Studies of football players have also shown that performing small-sided games is effective in improving VO_{2max}. For example, Impellizzeri et al. (2006) found that VO_{2max} increased to the same extent after a period with additional small-sided games compared with supplementary interval running sessions for experienced football players. Thus, it is clear that carrying out small-sided games is effective in improving VO_{2max}.

The effect of recreational football training on metabolic fitness

In the study by Krustrup et al. (2009a, b), solid evidence was provided that 12 weeks of recreational football has a marked impact on metabolic fitness for untrained men. Thus, fat oxidation during low- and moderate intensity exercise was elevated with a corresponding lowering of blood lactate, indicating a marked change in substrate utilization after training (Krustrup et al., 2009b), a finding that may well be related to peripheral muscular adaptations to football training such as a 23% increase in the number of muscle capillaries per fiber, elevated muscle enzyme activity and a muscle fiber type conversion from type IIX to type IIA fibers (Krustrup et al., 2009b).

After 12 weeks of football training, the fat mass was lowered by 2.7 kg and the LDL/HDL-cholesterol ratio was markedly changed, due to a significant decrease in LDL-cholesterol and a tendency for an increase in HDL-cholesterol (Krustrup et al., 2009a).

Table 2. Effects on body composition of short-term training for untrained subjects

Studies	Year	Duration (weeks)	Training-program: intensity (%) frequency (per week), duration of session (min)	Body mass	Fat-%	LBM	Leg bone mass	Total training duration (h)	Remarks
Aerobic training									
Krustrup et al. (Football)	2009a	12	82% HR_{max}, 3 per week, 50 min	1%↓*	12%↓*	3%↑*	3%↑*	30	
Krustrup et al. (Cont. run)	2009a	12	82% HR_{max}, 3 per week, 50 min	1%↓*	7%↓*	1%↑	1% ↔	30	
Meyer et al. (low+moderate intensity)	2007	12	71;79% HR_{max}, 5 per week, 35 min	2%↓	–	–	–	30	
Burgomaster et al. (endurance)	2008	6	65% VO_{2peak}, 5 per week, 50 min	0% ↔	0% ↔	–	–	25	
Stein et al. (low intensity)	1990	12	65% HR_{max}, 3 per week, 30 min	0% ↔	0%↓	–	–	18	
Stein et al. (moderate intensity)	1990	12	75% HR_{max}, 3 per week, 30 min	0% ↔	1%↓	–	–	18	
Ross et al.	2000	12	77% HR_{max}, 7 per week, 700 kcal/day	7%↓	18%↓*	2%↑	–	–	VO_{2max} 22%↑*
Schjerve et al. (moderate intensity)	2008	12	60–70% HR_{max}, 3 per week, 47 min	2%↓*	2%↓*	–	–	10	
Donovan & Brooks, 1983 (low intensity)	2005	24	60% VO_{2max}, 3 per week, 1200 kcal/week	1%↓	1%↓*	–	–	–	VO_{2max} 16%↑*
High-intensity training									
Nybo et al. (high intensity)	2010	12	> 90% HR_{max}, 3 per week, 5 × 2 min	1%↓	2%↓	0% ↔	0% ↔	6	
Stein et al. (high intensity)	1990	12	85% HR_{max}, 3 per week, 30 min	0% ↔	3%↓	–	–	18	
Schjerve et al. (high intensity)	2008	12	85–95% HR_{max}, 3 per week, 4 × 4 min	3%↓*	3%↓*	–	–	10	
Burgomaster et al. (sprinting)	2008	6	Wingate (500W), 3 per week, 4–6 rep	2%↓	4%↑	–	–	↔ h	
Donovan & Brooks, 1983 (high intensity)	2005	24	80% VO_{2max}, 3 per week, 1200 kcal/week	1%↓	6%↓*	–	–	–	VO_{2max} 22%↑*
Strength training									
Nybo et al. (strength)	2010	12	14 → 8 RM, 2 per week, 50 min	2%↑	2%↑	3%↑	3%↑*	20	
Cortez-Cooper et al.	2008	13	70% 1RM, 3 per week, 35 min	1%↑	3%↓	4%↑*	–	23	
Schjerve et al. (strength)	2008	12	90% 1 RM, 3 per week,?	1%↓	0% ↔	–	–	–	
Hu et al.	2008	20	Progressive 40–100% 1RM,? per week, 35 min	0% ↔	6%↓*	2%↑*	–	–	
Kokkinos et al. (low rep . hi res)	1988	10	4–5 RM, 3 per week,?	1%↑	6%↓	1%↑*	–	–	
Kokkinos et al. (hi rep . low res)	1988	10	14–16 RM, 3 per week,?	0% ↔	8%↓	2%↑*	–	–	
Hurley et al.	1988	16	10–20 RM, 3–4 per week,?	0% ↔	4%↓	1%↑	–	–	VO_{2max} 5%↑

LBM, lean body mass.

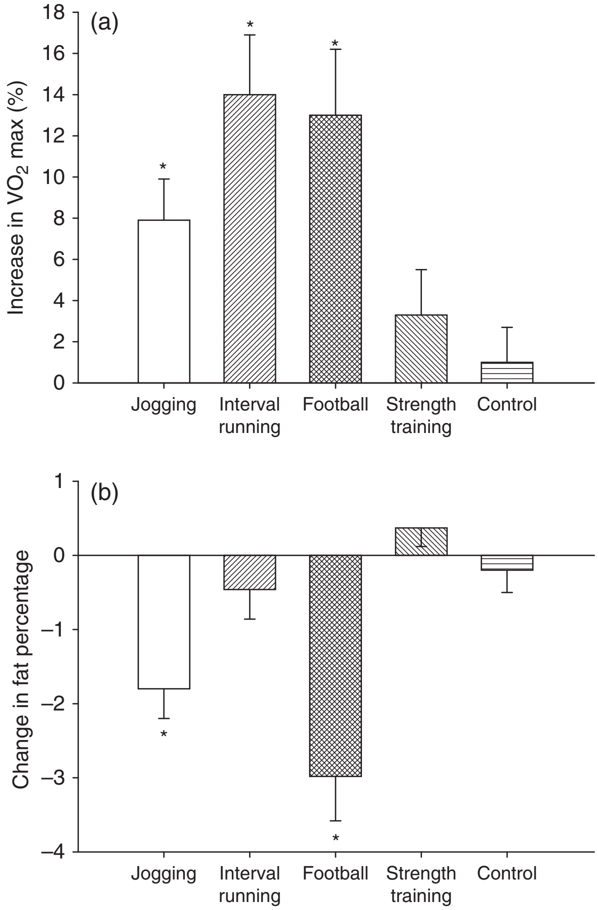

Fig. 2. Effect of 12 weeks of training for untrained males on changes in maximal oxygen uptake (a) and fat percentage (b) for different training regimes (jogging: open bars; interval running: crossed bars; football: crosshatched bars; strength training: crossed bars; control: horizontal lined bars). Values are presented as means ± SEM. *Significant intervention-induced changes.

Other studies using different types of fitness training have also demonstrated training-induced changes in HDL and LDL (Donovan & Brooks, 1983; Hurley et al., 1988; Stein et al., 1990; Miyachi et al., 2004; Table 1). In the study by Stein et al. (1990), aerobic training at three different intensities was compared. Low-intensity aerobic training for 12 weeks did not alter the HDL and LDL concentrations, but significant improvements were seen at the higher intensities (Table 1). Thus, a possible explanation for the difference in blood lipid profile response between football training and continuous running may be the larger amount of work performed at high intensities (Krustrup et al., 2009b). On the other hand, in a recent study, it was shown that neither plasma HDL nor LDL responded to short-term high-intensity intermittent running or to strength training (Nybo et al., 2010), and it is likely that also the total training volume is of importance for the cholesterol response, especially for HDL-cholesterol (Kokkinos & Fernhall, 1999; Durstine & Thompson, 2001; Durstine et al., 2001).

Table 3. Effects of short-term training for subjects on sub-maximal and maximal exercise response

Studies	Year	Duration (weeks)	Training-program: intensity (%) frequency (per week), duration of session (min)	VO_{2max}	RER submax	Blood lactate submax	HR submax	Total training duration (h)	Remarks
Aerobic training									
Krustrup et al. (Football)	2009a, b	12	82% HR_{max}, 2–3 per week, 50 min	13%↑*	7%↓*	60%↓*	11%↓*	30	
Krustrup et al. (Cont. Run)	2009a, b	12	82% HR_{max}, 2–3 per week, 50 min	8%↑*	4%↓	49%↓*	13%↓*	30	
Meyer et al. (low intensity)	2007	12	71% HR_{max}, 5 per week, 30 min	5%↑*	–	17%↓	5%↓	30	
Meyer et al. (moderate intensity)	2007	12	79% HR_{max}, 5 per week, 30 min	4%↑*	–	17%↓	9%↓*	30	
Van Hoof et al.	1989	16	?, 3 per week,?	14%↑*	–	–	–	–	
Jennings et al.	1986	4	65% (W_{max}), 3 per week, 30 min	11%↑*	–	–	12%↓	6	
Burgomaster et al. (end.)	2008	6	65% VO_{2peak}, 5 per week, 50 min	10%↑*	3%↓*	27%↓	8%↓*	25	
Schjerve et al. (moderate intensity)	2008	12	60–70% HR_{max}, 3 per week, 47 min	16%↑*	–	–	–	28	
High-intensity training									
Nybo et al. (high intensity)	2010	12	> 90% HR_{max}, 3 per week, 5 × 2 min	14%↑*	7%↓	33%↓*	7%↓*	6	
Perry et al.	2008	6	95% HR_{max}, 3 per week, 40 min	9%↑*	2%↓	43%↓*	–	12	Body mass unchanged
Burgomaster et al. (sprinting)	2008	6	Wingate (500W), 3 per week, 4–6 rep	7%↑*	1%↓*	17%↓	6%↓*	↔ h	
Hickson et al.	1981	9	90–100% VO_{2max}, 3 per week, 6 × 5 min	23%↑*	–	60%↓*	18%↓*	13 ↔ 5	
Schjerve et al. (high intensity)	2008	12	85–95% HR_{max}, 3 per week, 4 × 4 min	33%↑*	–	–	–	10	
Strength training									
Nybo et al. (strength)	2010	12	12–16 → 6–10 RM, 2 per week, 50 min	3%↑	7%↓	33%↓*	5%↓	20	
Shaw et al.	2005	8	60% 1RM, 3 per week, 60 min	14%↑*	–	–	–	24	Low baseline VO_{2max} (27)
Schjerve et al. (strength)	2008	12	90% 1RM, 3 per week,?	10%↑*	–	–	–	–	
Hickson et al.	1980	10	80% 1RM, 5 per week,?	↔	–	–	–	–	47%↑ bicycle TTE

RER, Respiratory exchange ratio; HR, heart rate.

Both for the football and a comparable running group, a significant decline in body fat percentage was observed (Fig. 2b), which is in coherence with other training studies at similar relative intensities and duration (Ross et al., 2000; Nybo et al., 2009; Table 2)). For groups that performed 12 weeks of intense interval training and short-term strength training, no changes were observed in fat mass (Fig. 2b), which may be related to the fact that the total energy expenditure was limited for the interval runners and that the strength training group had no changes in metabolic fitness as indicated by unchanged fat oxidation during exercise, lipid profile, capillarization and enzyme activities (Nybo et al., 2010).

Recreation football training over the 12-week period caused marked increases in lean body mass (Krustrup et al., 2009a). The improvement was similar to the effect observed after a 12-week strength training program and markedly higher than the non-significant effects observed for intermittent and continous running (Fig. 3a). Apart from the positive effect on strength and muscle function, an increased muscle mass *per se* has been shown to influence glucose tolerance, probably due to an increase in the total amount of glucose transporters (Ivy, 1997). Recently, it was substantiated by Babraj et al. (2009) who observed that only 2 weeks of short-term intermittent high-intensity exercise lowered the glucose and insulin levels markedly during an oral glucose tolerance test. Thus, short and intense exercise appears to be a powerful stimulus to improve insulin action. In the study by Krustrup et al. (2009a, b), no significant changes were observed in the glucose or insulin response after 12 weeks of training, which may be due to the fact that the pre-training levels were normal. In a training study where 3 months of football training and dietary advice was provided for a group of 47–49-year-old men with type II diabetes, the glucose tolerance and the muscle enzyme activity was markedly improved (Saltin et al., 1979), providing evidence that football has the potential to lower the risk of diabetes. Together, football training appears to be an efficient activtity to improve metabolic fitness by improving blood lipid profile, fat oxidation, capillary density, muscle mass and glucose tolerance.

The effect of recreational football training on musculo-skeletal fitness

Recently, the mean muscle fiber area was observed to increase in the lateral vastii muscle following a period of recreational football training in young and middle-aged untrained men, whereas high-intensity interval running and continuous running with a comparable group of men showed no effect on muscle fiber size

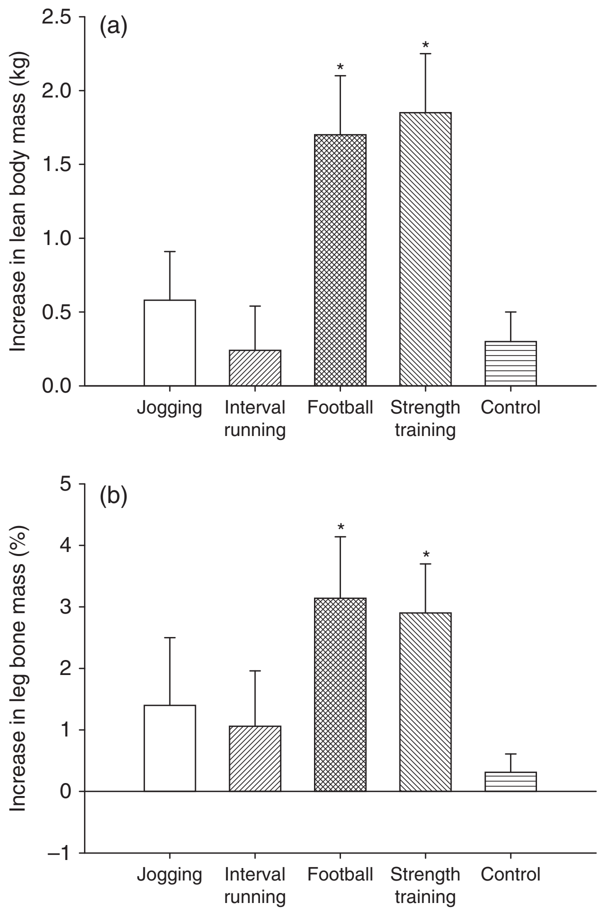

Fig. 3. Effect of 12 weeks of training on untrained males on changes in lean body mass (a) and leg bone mass (b) for different training regimes (jogging: open bars; interval running: crossed bars; football: crosshatched bars; strength training: crossed bars; control: horizontal lined bars). Values are presented as means ± SEM. *Significant intervention-induced changes.

(Krustrup et al., 2009b, Nybo et al. 2010). This finding suggests that the large number of forceful accelerations and rapid decelerations performed during football training may provide a high-force stimulus to the muscle fibers that is sufficient to activate intracellular signaling events leading to increased myofibrillar protein synthesis. Interestingly, the gain (15%) in the mean muscle fiber area observed after 12 weeks of football training (Krustrup et al., 2009b) was comparable in magnitude with that observed after 14 weeks of heavy-resistance strength training in young men (18%) (Aagaard et al., 2001). Typically, a 5–15% increase in anatomical muscle cross-sectional area and muscle volume can be observed following 8–12 weeks of training (Häkkinen et al., 1998; Aagaard et al., 2001; Reeves et al., 2004; Holm et al., 2008), whereas single muscle fiber area evaluated by muscle biopsy sampling is found to increase by 15–30% (Häkkinen et al., 1998; Aagaard et al., 2001; Cribb & Hayes, 2006; Kosek et al., 2006; Suetta et al., 2008). This apparent discrepancy may be explained by the corresponding changes in muscle architecture. In contrast, the muscle fiber area appears to remain unchanged in response to aerobic endurance training (Kraemer et al., 1995; McCarthy et al., 1995; Carter et al., 2001; Putman et al., 2004) including high-intensity interval running (Nybo et al., 2010), or to even decrease (Kraemer et al., 1995; Harber et al., 2004; Trappe et al., 2006).

The increases in the muscle fiber area induced by recreational football training and strength training represent an important adaptation mechanism in functional terms, as the magnitude of maximal contractile muscle force and power is proportional to the physiological cross-sectional of the muscle (i.e. single muscle fiber area) (Aagaard et al., 2001). In consequence, the training-induced increase in muscle fiber size (elevated physiological cross-sectional muscle area) is accompanied by increased levels of maximal muscle strength [torque, rate of force development (RFD)] in both young (Aagaard et al., 2001; Andersen et al., 2005) and aging individuals (Häkkinen et al., 1998; Esmarck et al., 2001; Suetta et al., 2008). Likewise, increases in maximal isometric hamstring strength and 30-m sprint performance were observed following 12 weeks of recreational football training in untrained males, arguably due to a major involvement of this muscle group during fast forward acceleration, i.e. when initiating a sprint (Krustrup et al., 2009b).

Strength training does not (or only to a minor extent) lead to changes in the relative proportion of slow-twitch (type I) vs. fast-twitch (type II) muscle fibers. In contrast, the relative proportion of type IIA vs. IIX muscle fibers may change substantially in response to resistance training. Thus, resistance training typically results in both a down regulation in type IIX fiber proportions with a corresponding upregulation in the proportion of type IIA muscle fibers, when evaluated by conventional histochemistry analysis (Staron et al., 1991) or by electrophoresis analysis of myosin heavy chain isoforms (Andersen & Aagaard, 2000). Notably, a similar pattern of reduced percentage type IIX fibers (from 18% to 11%) was observed recently following 12 weeks of recreational football training (Krustrup et al., 2009b), albeit the response was somewhat blunted compared with that seen with strength training. The training-induced conversion of IIX fibers into IIA fibers is of important functional significance both for athletes and non-athletes because the type IIA muscle fiber, yet powerful, is more fatigue resistant than the type IIX fiber type.

Elevated EMG amplitudes have been reported after strength training, indicating an increased neuromuscular activity during maximal voluntary contraction (Narici et al., 1989; Häkkinen et al., 1998; Van Cutsem et al., 1998; Aagaard et al., 2002). Notably, recreational football training over 12 weeks led to increased neuromuscular activity in the hamstring muscles during knee flexion MVC, which may explain the finding of a training-induced gain in maximal isometric hamstring strength (Krustrup et al., 2009b). No changes were observed for the quadriceps muscle (Krustrup et al., 2009b). Thus, recreational football training appears effective of eliciting adaptations in neuromuscular function, although the response is somewhat blunted compared with that achieved by strength training. These findings suggest that the neurogenic potential of high-intensity long-term recreational football training should be included for examination in future studies.

Parallel increases in rapid force capacity (RFD), EMG amplitude and rate of EMG rise have been observed in the initial phase (0–200 ms) of rising muscle force following strength training (Van Cutsem et al., 1998; Aagaard et al., 2002). Contractile RFD measured during maximal isometric quadriceps and hamstring contraction remained unchanged following 12 weeks of recreational football training, despite that the forceful muscle actions related to accelerations, decelerations, rapid turns and tackles might be expected to promote increased contractile RFD (unpublished data). However, we observed recently enhanced RFD characteristics in lifelong football-trained elderly males (69 years) compared with age-matched physically active controls (Sundstrup et al. 2010). Thus, it is possible that long-term football training (>3 months) could be affective of evoking adaptive changes in RFD.

Bone mass content and bone mass density

In the studies by Krustrup et al. (2009a,b), it was demonstrated that the untrained males achieved significant increases in leg bone mass after participation in recreational football training after only 12 weeks. In agreement, football players demonstrate higher whole body, spine, hip and leg bone mineral density (BMD) than inactive controls (Fredericson et al., 2007). As illustrated in Fig. 3, the increase in leg bone mass following 12 weeks of recreational football training was of a similar magnitude as the gains observed following strength training of the same duration, whereas neither recreational jogging nor high-intensity interval running induced changes in total or leg bone mass. In accordance, both male and female football players have higher hip and spine BMD than equally fit runners (Fredericson et al., 2007; Mudd et al., 2007). Furthermore, meta-analysis of cross-sectional studies reveals that participation in non-weight-bearing sports or physical activities with monotonous and stereotypic movement pattern appears to have little or no effect on bone mass or BMD, whereas strength-based and

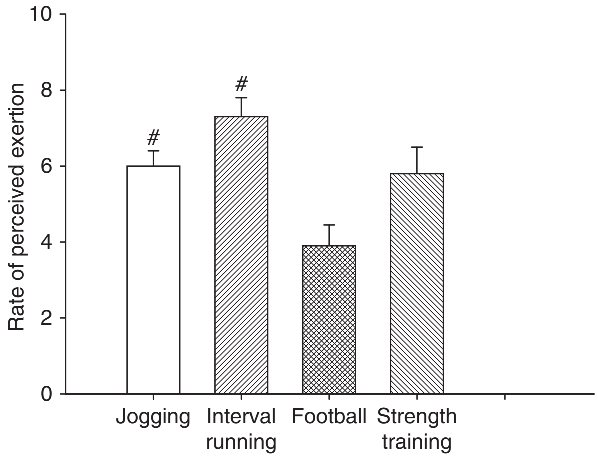

Fig. 4. Rate of perceived exertion for various types of training carried out by untrained males (jogging: open bars; interval running: crossed bars; football: cross hatched bars; strength training; crossed bars). Values are presented as means ± SEM. #Significantly higher than football.

high-impact sports are associated with higher BMD (Egan et al., 2006; Table 2).

Football training appears to provide a significant stimulus for bone mineralization as it is a highly intermittent sport, and the activity pattern in small-sided games is characterized by multiple turns, jump, several short sprints with accelerations and decelerations (Pedersen et al., 2009). This loading pattern results in high-impact forces on the skeletal muscles as well as the bones of the lower limb, and a high strain rate and a large magnitude of ground reaction and muscle forces are known to be important factors for providing an anabolic effect on osteogenesis. In addition, nutritional, endocrinological and genetic factors are also of vital importance for BMD and bone strength (New, 2001). However, the training studies that are summarized in Fig. 3 clearly demonstrate that participation in recreational football or strength training may lead to increases in bone mass even in the absence of nutritional intervention. Therefore, regular participation in recreational football training appears to be an effective stimulus for musculo-skeletal adaptations, which even in a short time frame (12 weeks) may evoke increases in both lean body mass and BMD. These adaptations may benefit the participants in a number of daily activities, and importantly may help to prevent the development of osteoporosis and stress fractures later in life (Fig. 3).

Another interesting aspect is that the football players, despite the frequent intense actions and periods with high aerobic loading, report lower perceived exertion than the joggers and the interval runners (Fig. 4). This finding may be linked to the football players being more focused on the playful elements of the game and the team mate interaction, which in turn may improve the possibility for long-term adherence to physical activity.

Recreational football and the risk of injury

Reasons to participate in sports and physical activity are many, such as pleasure and relaxation, competition, socialization, maintenance and improvement of fitness and health (Bahr & Holme, 2003). However, sport participation also carries a risk of sustaining injuries. Most studies on the epidemiology of sport injuries have been conducted in elite athletes and little knowledge is available regarding the relationship between recreational sports and its accompanying injuries.

According to the few studies that have followed subjects in 1 year (i.e. over a full season) and taken exposure data into account, the injury frequencies are fairly high in combined football match-play and training. For example, Parkkari et al. (2004) have reported an injury incidence of 7.8 injuries per 1000 h of football participation, which ranks football eight in 31 recreational and competitive sports. Running ranks 20 with an injury incidence of 3.6 injuries per 1000 h of participation, but no differentiation between the types of running has been made. From a clinical point of view, more injuries are suspected in high-intense interval running compared with jogging because it is known that peak join power increases with increasing running speed (Belli et al., 2002). In another study involving 31 620 inhabitants in a Swedish municipality, injury rates in persons attending a physician for an acute injury sustained during sports participation were reported (de Loes & Goldie, 1988). In this study, ice hockey and handball were found to have the highest risk followed by football. For males aged 15–59 years, the ranking was ice hockey, horseback riding, handball and football. If an injury incidence of 7.8 injuries per 1000 h of football participation is valid in recreation football in general, the implication is that the players would be exposed to one injury every 1.2 years if he carried out two 1-h sessions per week all-year round and one severe injury every ~ 13 years as the severity of most injuries in recreational football is mild to moderate with approximately 9% categorized as severe injuries, defined as injuries that result in missing of work or a corresponding activity for at least 1 day (Parkkari et al., 2004).

It should be emphasized that the above-mentioned injury incidences in football are the incidence for training and match play analyzed together. However, it is well known that for elite and amateur football players the injury risk per hour of activity is approximately 5–10 times higher during match-play than training (Poulsen et al., 1991; Hägglund et al., 2003; Arnason et al., 2004) with injury incidence from two to five injuries per 1000 h of participation in training sessions. For specific injury types the risk of injury, such as acute hamstring injuries, is > 15 times higher during match-play compared with training (Petersen et al., 2009). The study by Parkkari et al. (2004) documents that injury incidence in recreational and competitive sports decreases with an increasing age in both males and females aged 15–74 years, which is supported by Finch & Cassell (2006) who report an overall lower injury rate in persons aged 40+ years compared with persons aged 5–14 years and 15–39 years.

In the reviewed studies dealing with the fitness and health effects of recreational football and running, around 150 subjects have been followed over 3–4 months of training performed two to three times a week. During these studies, $<5\%$ of the footballers ($n=3$) and distance runners ($n=3$) contacted the in-house medical doctor regarding injuries, whereas 33% of the interval runners did ($n=5$). However, further studies are required to obtain more information about injury risk, types of injury, injury severity, etc. for various age groups playing recreational football organized as small-sided games among friends.

Summary

In summary, a short-term period (weeks) with recreational football leads to significant performance improvements and effectively stimulates musculoskeletal, metabolic and cardiovascular adaptations that are of importance for health. Recreational football involves aerobic high- and moderate intensity training as well as periods of high anaerobic loading with multiple intense actions high-speed runs, sprints, turns, jumps and tackles. This integration of different types of exercise appears to provide a major impact on the three main areas of fitness with a comprehensive impact on the risk of life-style diseases. Further studies, of which some are presented in this Supplementum, should provide an insight into the effects of recreational football for groups of subjects of different age, gender, social background as well as the long-term effects and compliance in recreational football training, including the influence of training volume and intensity on the range of physiological adaptations.

Key words: Soccer, VO_{2max}, fat percentage, muscle mass, bone mass, cardiovascular, metabolic, musculo-skeletal, fitness.

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