NORWEGIAN SCHOOL
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Prepare to fail or failing to prepare? Acute performance after FIFA 11+ with and without strength exercises

A randomised crossover study

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Abstract

Background: FIFA 11+ is an injury prevention warm-up program for football that includes a strength training part. Despite its proven effectiveness in reducing injuries, uncertainty remains about whether it could impair the following performance and if it should be considered an appropriate warm-up. Few studies on the acute effects of the program have been reported, with incongruent results.

Aim: To compare the acute post-exercise effects of FIFA 11+ (WU+S) and FIFA 11+ not including strength training (WU-S) on various physical performance measures.

Study design: Randomised crossover study.

Method: A total of 15 female junior football players completed WU+S and WU-S on separate days in randomised order. They were tested twice on each experimental session (pre-post warm-up) in isokinetic maximal voluntary contraction and countermovement jump. Sprint performance and RPE questionnaire were assessed post warm-up only.

Results: Players were slower on 20 and 30 m sprint after WU+S compared with WU-S ($P < 0.05$), with a tendency also observed in 10 and 40 m sprint times ($p < 0.06$ and $p < 0.052$, respectively). There was a significant difference in the change in peak torque between the two groups ($p < 0.05$). Peak torque in the WU+S group was reduced after performing the warm-up. RPE was higher after WU+S than WU-S ($p < 0.001$).

Conclusion: Performing the FIFA 11+ program as a warm-up routine with the strength training part impairs subsequent physical performance in female junior football players compared to performing the FIFA 11+ warm-up without the strength part.

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1. Theory

1.1 Introduction

This master thesis is about the warm-up before football team participation for female youth players. Warm-up is a preparatory activity preceding football to optimise performance and, consequently, a tool to facilitate further development for these players. Adolescent players are not the finished product, with many players treating each training session and game as an opportunity to improve their footballing ability and win. For players to improve, they have to cope with the demands of the game, with explosive actions being key determinants for performance. However, physical development in adolescence and increased training volume is associated with injuries, especially among female adolescents who demonstrate movement patterns characteristics attributed to neuromuscular deficits, making them more susceptible to injuries (Giza & Micheli, 2005, p. 142; Myer et al., 2013, p. 205). Injuries may lead to long-term absence from sports participation and medical bills and hinder further development (Maffulli et al., 2010, p. 32). Consequently, sports injury prevention programs have become an area of interest.

In the past decades, the warm-up has been targeted as a venue for injury preventive measures, and several interventions have been developed and tested. In 2006, Fédération Internationale de Football Association's (FIFA) Medical and Research Centre (F-MARC) developed the FIFA 11+ injury prevention program, a warm-up routine that consists of three parts: 1) running exercises, 2) strength, plyometrics and balance, 3) running exercises. Randomised controlled trials have proved that the program can reduce injury risk in junior football players (Soligard et al., 2008, p. 6; Steffen et al., 2013, p. 6). The injury preventive effect of the FIFA 11+ program is likely to be twofold, an acute increase in physical preparedness through the common physical acute enhancements from general warm-up and the long-term effect of the strength or proprioceptive training programme (i.e. players becoming stronger or improving their balance).

FIFA 11+ includes five strength exercises as an integral part. If one expects long-term strength adaptation, it is important that the strength volume is large enough to elicit adaptation. However, long-term adaptation from strength stimulus is expected to result from training volume where an acute fatigue response will occur. Physically demanding tasks such as strength training result in an acute decline in muscle function (Palucci Vieira et al., 2021, p. 662). One of the exercises in the program is the Nordic hamstring exercise, which has previously shown to be effective in reducing hamstring injuries among football players when performed before and after practice (Arnason et al., 2008, p. 44; Petersen et al., 2011, p. 2301; van der Horst et al., 2015, p. 1320). Given the eccentric high-intensity nature of the exercise, if performed before training, it is likely that an acute reduction in maximal hamstring force will occur before the most crucial parts of the training session begins, which can impair physical abilities related to elite performance. This reduction would be strictly opposed to the purpose of warm-ups, and unnecessary as the Nordic hamstring exercise can prevent injuries when performed before and after practice (Small et al., 2009, p. 1081).

Therefore, this study aims to investigate whether strength training stimulus in FIFA 11+ are decreasing performance directly after completion.

1.2 Warm-up

Warm-up is a preparatory activity intended to perform two primary functions; (I) to improve muscle dynamics so that it is less inclined to injury, and (II) to prepare the athlete for the following activity (Woods et al., 2007, p. 1090). Warm-up affects not only a particular muscle, but the whole body (Safran et al., 1989, p. 243). Warm-up can either be passive or active (Bishop, 2003a, p. 440). Passive warm-up involves raising the body temperature by external means, e. g. diathermy, heating pads, saunas, hot showers, or baths. Active warm-up involves exercise and is likely to induce greater metabolic and cardiovascular changes, leading to increased preparedness in the subsequent exercise task (McGowan et al., 2015, p. 1543). Active warm-up can further be classified as either general or specific warm-up (Woods et al., 2007, p. 1090). The general active warm-up includes any non-specific body movements such as jogging or cycling. In contrast, specific warm-up utilises stretches and movements specific to the sport one is preparing for (McGowan et al., 2015, p. 1543).

Active warm-up and stretching are the two methods of exercise that are primarily utilised before recreational and competition activities (Shellock & Prentice, 1985, p. 268). Typically, warm-ups are composed of submaximal aerobic activity, stretching and a sport-specific activity (Behm & Chaouachi, 2011, p. 2633). Stretching is incorporated into warm-up protocols for injury prevention and improvement of performance (Safran et al., 1989, p. 244; Shellock & Prentice, 1985, p. 275). However, this is unclear, as numerous studies have reported varying results investigating different stretching techniques. The objective of stretching in a warm-up is usually to achieve a short-term increase in the range of motion (ROM) of a joint or to induce muscle relaxation and decrease the stiffness of the muscle-tendon system (Young & Behm, 2002, p. 33).

1.2.1 General warm-up

General warm-up is probably the most used warm-up technique and increases overall body temperature through active movements of the major muscle groups (Shellock & Prentice, 1985, p. 268). This type of warm-up is not necessarily associated with the neuromuscular components involved in the following athletic activity or event. The benefit of this warm-up procedure is that the deep musculature temperature (T_m) is elevated more quickly. Hence, the performance advantages that are directly related to an increase in muscle and core temperature can be attained by a general warm-up. With this in mind, interest has risen in targeting and including other components to add further benefits attained to warm-ups.

1.2.2 Warm-up/stretching protocols

Stretching is a common component in warm-up protocols (Opplert & Babault, 2018, p. 300). Stretching is supposed to elicit an increase in an athlete's flexibility, boosting athletic performance. Lack of flexibility may result in uncoordinated and awkward movements and probably end in decreased performance capabilities, i.e., sprint, with unelastic hamstring muscles likely losing some speed (Shellock & Prentice, 1985, p. 272). Stretching techniques include static, ballistic, proprioceptive neuromuscular facilitation and dynamic stretching (Young & Behm, 2002, p. 33). Static stretching was in the past considered to be an essential part of warm-up routines but has since been shown to adversely affect strength and explosive muscle performance (Beckett et al., 2009, p. 446; Buttifant & Hrysomallis, 2015, p. 658; Kistler et al., 2010, p. 2282). Dynamic flexibility is necessary for athletic performance due to the importance of athletes being able to move sport-specific in a non-restrictive range of motion (Shellock & Prentice, 1985, p. 272). Performing dynamic stretching in a warm-up has been shown to acutely increase muscular contractility and potentiate activities such as sprinting and jumping (Needham et al., 2009, p. 2619; Yamaguchi et al., 2007, p. 1243). Adding sport-specific dynamic stretches or movements to a warm-up may benefit subsequent performance.

1.3 Football

1.3.1 Physical demands in football

Football is an aerobic sport that involves frequent bouts of high-intensity actions (Bangsbo et al., 2006, pp. 666-667). Players cover 8-13 km during a match. This distance is covered with an intermitted movement pattern, and includes changes in intensity, direction, and mode of movement (Drust et al., 2007, pp. 784-785). Only 1.2-2.4% of the distance covered in a match is spent with the ball, and 90 s being the average ball time for each player, suggesting that movement "off the ball" to create space for teammates to play the ball, deceive opponents, or track opponents' runs is imperative in football (Di Salvo et al., 2007, p. 224; Reilly et al., 2000, p. 670). Performance is dependent on the interaction of awareness, decision making, technique, tactical and physical aspects, with the technical and physical demands constantly increasing (Barnes et al., 2014, pp. 1096-1099; Dellal et al., 2012, p. 958). In football, players perform passing, shooting, jumping, dribbling, change of direction, acceleration, and sprints. Sprint and jumping ability are crucial elements in performance, and are involved in ball possession and repossession, defensive play, corner kicks and attacks on goal (Di Salvo et al., 2009, p. 206; Haugen et al., 2012, p. 340). During match play, a sprint bout occurs approximately every 90 s, lasting 2-4 s on average (Stølen et al., 2005, p. 503). Sprinting accounts for 1-4% of total distance covered during a match, corresponding to 0.5-3.0% of effective playing time, i.e., when the ball is in play (Di Salvo et al., 2009, p. 207; Stølen et al., 2005, p. 503). Sprinting is the most frequent action in goal situations and is the most frequent powerful action prior to scoring for the goal scorer and the assisting player, as it enables a player to escape the opponent and reach a free zone to shoot on goal or make a decisive pass (Faude et al., 2012, p. 627). Jumping is the second most frequent action leading to scoring (Faude et al., 2012, pp. 628-630). Goals scored by jumping are relevant through headers after crosses or set pieces and are particularly relevant for defenders in these situations when defending. This highlights the importance of physical performance in football, given its significant contributions to game-changing moments.

1.3.2 Injuries in football

Football-related injuries are common (Arnason et al., 2008, p. 5). Most injuries are caused by trauma resulting from contact with another player or a non-contact injury occurring during running or turning (Junge & Dvorak, 2004, p. 930). The rate of injuries depends on several factors, including age, playing level, position on the field, environment, location and timing of the injury, and sex (Silvers-Granelli et al., 2015, p. 2). Higher injury rates have been reported in female junior players than in other age groups, with injury locations most common in female players being the knee (7-32%), ankle (9-31%) and thigh (6-22%) (Faude et al., 2005, p. 1697; Giza & Micheli, 2005, p. 142; Steffen et al., 2008, p. 605). Concern in female sports is the risk for serious knee injuries, such as anterior cruciate ligament injuries (Faude et al., 2005, pp. 1696-1697). In junior football, girls are reported to be five times more at risk for anterior cruciate ligament injury than boys (Mandelbaum et al., 2005, p. 1004), which underlines the importance of injury prevention in this population.

1.4 FIFA 11+

FIFA 11+ is a warm-up program designed to reduce injuries in female and male football players aged 14 and above (Bizzini et al., 2008, p. 5) aiming to improve muscular strength, proprioception, agility, and neuromuscular control during static and dynamic movements.

Figure 1. *Illustration of two out of six running exercises included in the first part of the FIFA 11+ program. Running straight ahead (left) and running hip out (right).*

FIFA 11+ consists of three parts and takes approximately 20 min to complete. The first part involves running exercises. The second part focus on core and leg strength, balance, and agility. The third part includes high-intensity running exercises with cutting movements. The strength training part includes five exercises and offers three levels of variation and progression. The FIFA 11+ has proven to be effective in risk reduction of severe injuries in junior female football players (Soligard et al., 2008, p. 6). Overall significant injury reductions of 32-50% and 72% in injury rate have been reported in teams that perform FIFA 11+ at least twice a week (Soligard et al., 2008, pp. 5-6; Steffen et al., 2013, p. 6). Compliance to the program was high (72% and 80%), and players with higher compliance had a significantly lower injury risk than players with low compliance. Another study found no significant injury reduction in the intervention group, with compliance reaching 52% (Steffen et al., 2008, pp. 608-609), indicating that high compliance to the program is necessary to lower injury risk (Soligard et al., 2010, p. 792).

Compliance with the FIFA 11+ program is a challenge (Lovell et al., 2018, p. 665). The head coach is usually responsible for the chosen warm-up activity used for their team (Judge et al., 2020, p. 2). Implementation of the complete FIFA 11+ program is not common practice, and the program is rarely used for its preventive injury purpose (Al Attar et al., 2018, p. 120; Bizzini et al., 2013, p. 803; Judge et al., 2020, p. 4). Coach and player motivation and experience may affect adherence to the program with time constraints and lack of football-specific activities also perceived as barriers to compliance with the program (McKay et al., 2014, pp. 5-6; Soligard et al., 2010, p. 791). The low implementation may also be due to the fatiguing nature of the exercise components or the degree of soreness the program can elicit (Lovell et al., 2018, p. 665). Losing valuable time for technical training with the ball and players not reaping the benefits from the warm-up contradicts the performance-enhancing purpose of warm-up.

1.5 Physiological effects of warm-up

1.5.1 Increased muscle metabolism

An increase in body temperature is one of the main objectives of warm-up (McGowan et al., 2015, p. 1524). Temperature is an essential factor in skeletal muscle contractile and metabolic properties (Gray et al., 2006, p. 376). Fast skeletal muscles consume adenosine triphosphate (ATP), the immediate resource for muscle contractions. (Bonora et al., 2012, p. 343; Hargreaves & Spriet, 2020, p. 817; Yamada, 2017, p. 21). ATP availability is critical in explosive-power or sprint events lasting for seconds or minutes, and more intermitted sports, including football (Hargreaves & Spriet, 2020, p. 817). During intense efforts lasting seconds or in ball sports, most ATP is derived from phosphocreatine (PCr) and glycogen (Hargreaves & Spriet, 2020, p. 817; Rose & Richter, 2005, p. 260). Increasing T_m by warm-up leads to greater ATP and PCr utilisation in the working muscle, resulting in faster ATP turnover (Gray et al., 2011, p. 892). Elevation of T_m is associated with quicker ATP turnover via greater PCr utilisation and increases in muscle glycogen breakdown (Febbraio et al., 1996, p. 1253; Gray et al., 2011, pp. 5-6; McGowan et al., 2015, p. 1524; Rose & Richter, 2005, p. 260). The increase in anaerobic ATP turnover will likely enhance performance in high-intensity activities such as sprinting and stop-and-go sports, with numerous transitions from low-intensity to high-intensity (Hargreaves & Spriet, 2020, p. 824).

1.5.2 Muscle-tendon unit

One other possible effect of raising T_m is decreasing muscle viscosity, lowering resistance to stretch and increasing ROM (Bishop, 2003a, p. 441). Muscles generate force transmitted via connective tissue networks and tendons, which produce joint motions, known as the muscle-tendon unit (Finni, 2006, p. 147; Fukunaga et al., 1997, p. 457). The force is transferred to the connective tissue containing myotendinous and myofascial pathways, the passive mechanical properties of muscle, referred to as stiffness, which is the relationship between joint angle and passive torque (Herbert, 1988, p. 142; Herda et al., 2014, pp. 62-63). This stiffness decrease with increased temperature due to altering the stable bonds between actin and myosin filaments (Bishop, 2003a, pp. 441-445). Warm-up can minimise muscle stiffness by moving the required muscle group through their ROM (Wiktorsson-Möller et al., 1983, p. 251). Consequently, altering the actin-myosin bond can reduces the passive stiffness of the muscle (Bishop, 2003a, p. 445). Decreases in passive torque and passive stiffness have been reported following two min of dynamic stretching (Herda et al., 2014, p. 64; Konrad et al., 2017, p. 1072). Muscle stiffness is also dependent on the structural arrangement of muscle and change in fluid friction, i.e. viscosity, which plays a significant role in muscle stiffness change and is likely due to rearrangement/slipping of collagen fibres (McNair et al., 2002, p. 540; Nordez et al., 2009, pp. 78-80). Elevated temperature may decrease muscle fibres' stiffness during contraction and consequently reduces passive torque and muscle-tendon stiffness, resulting in smoother contractions (Bishop, 2003a, p. 441; Opplert & Babault, 2018, p. 318; Woods et al., 2007, p. 1096). Under these circumstances, players will likely increase their flexibility resulting in more fluent and efficient athletic movements and less susceptibility to injury.

1.5.3 Muscle contractility

Muscle contractions produce heat, and T_m is directly proportional to the relative work rate (Bishop, 2003a, p. 441; Yamada, 2017, p. 21). When the warm-up begins, heat production will increase T_m within seconds and affect muscle contractility (Racinais et al., 2017, p. 228). This rise in Tm affects the contractile function of type I and II fibres (Gray et al., 2006, p. 380; McGowan et al., 2015, p. 1525). Type II fibres are fast-twitch muscle fibres, with a maximum unloading velocity approximately ten times faster than type I, making them the most important in explosive performance tasks such as sprinting (Ross & Leveritt, 2001, pp. 1070-1071). Type II fibres benefit from increased

T_m when the contraction frequency of the activity is high, and vice versa for type I fibres (McGowan et al., 2015, p. 1525). Elevating T_m results in greater rate of PCr and ATP utilisation, and power output in type II fibres. Given the significance of type II fibres in sprinting, an essential physical determinant for football performance, the increased power output in type II fibres due to elevated temperature should be one of the goals of warm-up.

1.5.4 Muscle contraction velocity

Further higher power output can also result from elevated T_m increasing muscle fibre conduction velocity (MFCV; McGowan et al., 2015, p. 1525; Racinais et al., 2017, p. 228). Performance and ATP turnover may be affected by neuromuscular factors, with increased T_m possibly improving performance by augmenting the nervous system's function and increasing the transmission speed of nervous impulses (Bishop, 2003a, p. 443; Gray et al., 2006, p. 376). Enhanced nervous system function is vital for tasks requiring high levels of complex body movements or rapid reactions to various stimuli often associated with sports. Elevated T_m can positively alter the force-velocity relationship and concurrently the power-velocity relationship, resulting in higher power outputs in exercise tasks (De Ruiter & De Haan, 2000, p. 169; McGowan et al., 2015, p. 1525). MFCV is the average value of conduction velocities of the motor units active during a contraction (Andreassen & Arendt-Nielsen, 1987, p. 561). Increased MFCV is often explained by the recruitment of larger motor units or a rise in T_m, likely due to a temperature-mediated effect on voltage-gated Na^+ channels (Gray et al., 2006, p. 379; Schmitz et al., 2012, pp. 1593-1594). Depolarisation of a nerve axon is due to the abrupt influx of NA^+ ions, which may occur as a result of the opening of voltage-gated channels along the axon or to the binding of a neurotransmitter (Rutkove, 2001, pp. 869-870). Action potentials are affected by temperature variations, with a rise in temperature accelerating the opening and closing of these channels, allowing less Na^+ to enter the cell (Gray et al., 2006, p. 379; Rutkove, 2001, p. 870). A subsequent decrease in action potential amplitude, duration and area follow, leading to a more rapid onset depolarization, producing a faster MFCV (Gray et al., 2006, p. 379). More immediate action potential delivery to the muscle fibres leads to greater Ca^+ release from the sarcoplasmic reticulum, leading to a quicker rate of cross-bridge cycling, hence requiring a greater rate of ATP turnover.

An increase in T_m is reported to elicit enhancement in both MFCV and power via a reduction in time to reach peak twitch and increased rate of force development (Gray et al., 2006, p. 381). Strength- and power-demanding sports like football require fast rate of force development to attain the highest possible peak power output within a short timeframe (McGowan et al., 2015, p. 1525), which suggests that MFCV is an essential factor to target in warm-up routines.

1.5.5 Oxygen uptake

Another factor is oxygen uptake, with oxygen delivery increasing in response to active warm-up (Bishop, 2003a, p. 443). Warm-up changes the time course of the pulmonary VO_2 response within a subsequent high-intensity exercise task by speeding VO_2 kinetics (McGowan et al., 2015, p. 1526). The temperature rise elicits an increase in the amplitude of the primary VO_2 response and a reduction in the VO_2 slow component. The VO_2 slow component is slowly developing an increase in VO_2 during constant-work-rate exercise above the lactate threshold and is associated with progressive loss of muscle contractile efficiency and development of fatigue (Jones et al., 2011, p. 2047). Muscle blood flow increases in response to warm-up (Gerbino et al., 1996, p. 106; Jones et al., 2006, p. 1437). Probably due to reduced oxygen tension, increased potassium (K^+) concentration and increased hydrogen ion (H^+) concentration causing vasodilation and increased muscle blood flow through active tissue (Bishop, 2003a, p. 443; Jones et al., 2006, p. 1437). This increase in muscle blood flow coupled with more efficient oxygen separation from haemoglobin at higher temperatures providing more oxygen to the working muscles, results in improved exercise tolerance and mean power output (Bishop, 2003a, p. 441; Goulding et al., 2020, p. 819; McGowan et al., 2015, p. 1526; Woods et al., 2007, p. 1091).

Baseline VO_2 may also be elevated following warm-up (Bishop, 2003a, p. 443; Gerbino et al., 1996, p. 104). Elevated VO_2 baseline benefits following work requirements with less of the initial work completed anaerobically, leaving more of the anaerobic capacity for later use e.g., the final sprint of the game (Bishop, 2003a, p. 444). Initial sparing of the anaerobic capacity and the improved VO_2 kinetics would increase time to exhaustion and improve performance in sports requiring significant anaerobic contributions, such as football.

1.6 Strength training during warm-up

1.6.1 The Nordic hamstring exercise

Exercise-induced muscle damage is common after performing unaccustomed exercises or exercises with increased duration or intensity (Byrne et al., 2004, p. 50). FIFA 11+ includes five strength exercises, including regular and sideways bench, squats, jumping and the Nordic hamstring exercise (NHE; Bizzini et al., 2008, p. 29). The hamstrings are of particular interest in football as they are strongly stressed during the rapid changes from eccentric to concentric phase of contraction, e.g. during kicking or sprinting, postulating that they are essential for performance and injury-prone (Beijsterveldt et al., 2012, p. 1; Croisier et al., 2008, p. 1470). The NHE is proven effective in preventing hamstring injuries in football players when performed before and after training (Arnason et al., 2008, p. 44; Petersen et al., 2011, p. 2301; van der Horst et al., 2015, p. 1320). It is an eccentric exercise performed on the knees with ankles held/strapped with subjects lowering their upper body towards a prone position as slow as possible (Cuthbert et al., 2020, p. 84). The slow eccentric movement gives a stimulus whereby the myosin heads are already attached to the actin and forced to detach by the lengthening of the cross bridges, resulting in muscle damage. During active lengthening of a muscle fibre, the further a muscle is stretched onto the descending limb of the length-tension curve, the greater potential for damage (Byrne et al., 2004, p. 61). Eccentric training elicits greater adaptive responses when compared to concentric training regarding both muscle strength and architecture, which is why the NHE is an effective injury prevention strategy (Arnason et al., 2008, p. 44; Cuthbert et al., 2020, p. 85; Mjølsnes et al., 2004, p. 314). However, eccentric exercise selectively recruits and damages type II fibres and presumably compromises performance ability after damage. This likely results in a decrease in speed and power right after the exercise. Reduction in the muscles' force-generating capacity and velocity of shortening are central to the reduction in power output and may impair muscle function at higher angular velocities, i.e., sprinting (Byrne et al., 2004, pp. 61-62). Eccentric exercise resulting in muscle damage reduces dynamic strength and adversely affects dynamic multi-joint movements associated with athletic performance (Byrne et al., 2004, pp. 64-65). The easiest level of difficulty, level 1, in the FIFA 11+ strength protocol includes performing one set of three to five repetitions of the NHE (Bizzini et al., 2008, p. 42).

Figure 2. *Start (1) and end (2) position of the Nordic hamstring exercise.*

Performing one set of five repetitions of NHE before football training results in hamstring fatigue (Lovell et al., 2016, pp. 10-14; Marshall et al., 2015, pp. 3129-3131). Greater peak torque declines were observed during football training when NHE was done prior compared to after training. The effect of NHE on fatigue was angel-specific, with the greatest strength loss at elongated muscle length. The NHE has demonstrated a similar increase in eccentric hamstring strength over a 12-week training period irrespective of scheduling the NHE before or after football training (Lovell et al., 2018, p. 663). Performing NHE after training may be more beneficial. Eccentric hamstring strength is more efficiently maintained during simulated match play when NHE is part of the cool down instead of the warm-up (Small et al., 2009, p. 1081). Reduced football-specific fatigue during later stages of gameplay will likely lower hamstring injury risk and presumably elicit performance benefits as more muscle strength is maintained.

1.6.2 Potentiation

Post-activation potentiation (PAP) refers to the acute enhancement of muscular performance following contractile history (Sale, 2002, p. 138). PAP is induced by a maximal or near-maximal voluntary contraction (Tillin & Bishop, 2009, p. 148). Proposed mechanisms which may improve subsequent physical performance include an increase in recruitment of higher-order motor units, increased reflex electrical activity in the spinal cord, and phosphorylation of myosin regulatory light chains, which increases Ca^{2+} sensitivity of the myofilaments (McGowan et al., 2015, p. 1527; Sale, 2002, p. 138; Tillin & Bishop, 2009, p. 148). Phosphorylation achieved by a contraction is lost after 5-6 min of inactivity, meaning that any potentiated effect on performance can only be effective within a short timeframe (1-5 min) after the conditioning contractions (Macintosh et al., 2012, p. 547). Contractile activity produces fatigue and PAP (Robbins, 2005, p. 453). Fatigue reduces contractile response, and potentiation enhances contractile response (Macintosh et al., 2012, pp. 547-548). The balance between the two determines whether the subsequent contractile response is enhanced, diminished or unchanged (Robbins, 2005, p. 453).

PAP has been proposed to be the main objective of warm-up (McGowan et al., 2015, p. 1541). Studies on potentiated performance subsequent warm-up have rarely implemented a comprehensive, appropriate, or task-specific warm-up routine (Blazevich & Babault, 2019, p. 13). In studies that imposed a warm-up, routines have typically included light aerobic exercise (5 min of running or cycling at a comfortable pace), potentially followed by muscle stretching and, on occasions, body-weight resistance exercises or athletic drills. Such warm-ups do not reflect the practices of athletes' preparation for training or competition. It is unclear if strength/conditioning exercises would potentiate performance enhancement in applied settings where participants complete a comprehensive, specific warm-up routine. With a task-specific comprehensive warm-up provided, results showed no potentiation in change of direction performance in athletes when using an isometric squat as part of the warm-up (Marshall et al., 2019, p. 1555). However, ballistic condition activity of horizontal plyometric exercise included in a complete and specific warm-up potentiates sprint acceleration performance over 10 m and 20 m (Turner et al., 2015, p. 345). Furthermore, adding two sets of eight plate jumps (mass of 11.2 kg) to a complete warm-up routine improves 20 and 40 m sprint performance (Creekmur et al., 2017, p. 554). These findings support the meta-analysis of Wilson et al. (2013, p. 855), indicating that the preloading stimuli do not need to be of a hefty load to potentiate performance and postulates that task-specific comprehensive warm-ups should enhance performance if designed correctly.

1.6.3 Proprioception

Proprioception is the conscious and unconscious awareness of joint position, movement and force, heaviness, and effort (Lephart & Fu, 1995, p. 97; Riemann & Lephart, 2002, p. 73). Proprioception is processed in the central nervous system and is combined with other somatosensory, visual, and vestibular information before ending in a final motor command that coordinates the skeletal muscles' activation patterns (Röijezon et al., 2015, p. 368). Coordination involves a cooperative interaction between the central nervous system and the skeletal muscles and includes proprioceptive abilities (Ergen & Ulkar, 2008, p. 196). These abilities are fundamental in high-intensity football situations, such as running, acceleration, deceleration, cutting, dribbling, and jumping (Padrón-Cabo et al., 2020, p. 219). Proper coordination and proprioceptive abilities are also paramount in avoiding football injuries (Ergen & Ulkar, 2008, p. 196).

Eccentric training impairs proprioceptive abilities in the exercised muscle (Brockett et al., 1997, p. 255). Givoni et al. (2007) and Da Silva et al. (2021) evaluated knee position sense with a bilateral matching-task test acutely after muscle fatigue induced by unilateral eccentric exercise. Both studies found proprioception and position sense ability to be disturbed in the quadriceps muscle, with participants perceiving their exercised muscle to be longer than it is, resulting in matching error (Da Silva et al., 2021, p. 226; Givoni et al., 2007, p. 115). Furthermore, eccentric exercise increases the reaction of the knee joint angle to realise, i.e., disturbing the joint's ability to organise a rapid response to a disturbance in its position (Paschalis et al., 2007, p. 501). Position errors induced by eccentric and concentric exercises have also been reported in elbow flexors (Walsh et al., 2004, p. 711). The size of the positional errors after exercise is directionally proportional to the fall in active muscle force from fatigue (Proske, 2019, p. 2457). Suggesting that performing complex body movement tasks after a warm-up, including eccentric exercise, e.g., body feints coupled with the impaired proprioceptive ability, will probably result in less efficient movements and possibly a higher risk of injuries.

1.6.4 Fatigue

Warm-up needs to be sufficient in intensity and duration and simultaneously not elicit significant fatigue (Bishop, 2003b, p. 496). Fatigue inhibits force generation and muscle motor control capabilities (Pajoutan et al., 2017, p. 2). Performing a motor task for long periods induces fatigue (Lorist et al., 2002, p. 313). Fatigue refers to a decrease in a person`s ability to exert force and can be induced by various mechanisms such as strength training (Bigland-Ritchie et al., 1986, p. 137; Enoka & Stuart, 1992, p. 1632). It is an ongoing dynamic process during high-intensity exercise involving complex mechanisms that temporarily limit the power-producing capabilities of the integrated neuromuscular system (Poole et al., 2016, p. 2320). The development of fatigue can be categorised as either peripheral or central (Davis & Bailey, 1997, p. 45). Peripheral fatigue is due to impaired muscle function, and central fatigue is a reduction in the capacity of the central nervous system to activate muscles (Carroll et al., 2017, p. 1068). Fatigue in performance is proposed to have two characteristics; (I) performance fatigability, the decline in an objective measure of performance over a distinct period, and (II) perceived fatigability, the changes in the subjectively perceived effort necessary to exert the desired force or power output (Davis & Bailey, 1997, p. 46; Enoka & Duchateau, 2016, p. 2229; Enoka & Stuart, 1992, p. 1631).

1.6.4.1 Central fatigue

Central fatigue can be defined as failure to maintain the required force or power due to the failure of the central nervous system to drive motor neurons and muscle fibres (Amann, 2011, p. 2039). This leads to progressive reduction in voluntary activation during exercise, which can significantly decline power and force production during fatiguing exercises (Hunter, 2018, p. 2). Fatigability during exercise is often accompanied by an increase in the perceived effort necessary to exert desired force and eventually failure in the exertion of that force (Twomey et al., 2017, p. 97). When the force a muscle can produce is reduced, the perceived effort for that task increases with the more substantial motor command that the subject must generate to attain the target force (Davis & Bailey, 1997, p. not available). Fatigue impairs cognitive function and alters executive function (Boksem et al., 2006, p. 130). In football, skilled performance requires quick and accurate decision making and the ability to initiate and stop, monitor and change actions, and plan subsequent moves (Sun et al., 2021, p. 2). Starting the main activity in a state of fatigue may impair physical performance and players' decision making and technical performance during training.

1.6.4.2 Peripheral fatigue

Warm-up consisting of moderate to high-intensity activity may lead to a higher level of fatigue, impairing performance (Bishop, 2003b, p. 487). Muscle fatigue is an exercise-induced reduction in maximal voluntary muscle force (Enoka & Duchateau, 2016, p. 2229). Intense skeletal muscle activation generally results in impaired contractile function (Westerblad et al., 2010, p. 3095). The greater muscle force produced during a task, the more rapidly the muscle fatigues (Enoka & Stuart, 1992, p. 1636). The Nordic hamstring is a high-intensity eccentric exercise (Ishøi et al., 2018, p. 1663; Mjølsnes et al., 2004, p. 312). Greater forces are generated during eccentric contractions than concentric and isometric for a given angular velocity (Hody et al., 2019, p. 2).

Performing the Nordic hamstring exercise as part of a warm-up will potentially reduce maximal hamstring force prior to the main footballing activity and impair performance.

1.7 Power and force

Explosive strength refers to the ability to increase force as quickly as possible i.e., exerting a high rate of force development (Maffiuletti et al., 2016, p. 1091). The ability to quickly generate explosive muscle force is an important factor of performance in football, given its intermitted nature, with explosive-type muscle actions every few seconds (Thorlund et al., 2009, p. 273). Power is the ability to produce as much force as possible in the shortest possible time (Stølen et al., 2005, p. 523). Power is co-dependent on maximal strength, with an increase being connected with an improvement in relative strength and power abilities (Stølen et al., 2005, p. 503). Professional football players perform about 50 turns during a game, compromising of forceful contractions, to maintain balance, dribble and control the ball against defensive pressure (Stølen et al., 2005, p. 523). Given the significance of these factors in relation to football performance, it is imperative that a warm-up is structured in a way that enhances these abilities and not impair them.

1.8 Performance measurements

1.8.1 Isokinetic dynamometry

Isokinetic dynamometry is considered the gold standard to measure knee extensor and flexor strength accurately (Zapparoli & Riberto, 2017, p. 556). It is an objective measuring method of muscle function in variables related to torque, power and endurance with accommodating resistance throughout a joint’s range of motion (Drouin et al., 2004, p. 22). This method is frequently used in assessing football players’ anterior-posterior balance and in intra-limb asymmetries in strength for monitoring both performance and injury prevention purposes (Coratella et al., 2018, p. 82; Croisier et al., 2008, p. 1470; Ostenberg et al., 1998, p. 258). To evaluate effect on physical performance, isokinetic testing of knee extension and flexion is often used (Brito et al., 2010, p. 212; Coratella et al., 2018, p. 82; Daneshjoo et al., 2012, p. 282).

Isokinetic dynamometry testing is a safe and reliable test method. Several studies have consistently shown that testing demonstrates excellent test-retest reliability and reproducibility (Habets et al., 2018, p. 4; Nugent et al., 2015, p. 213; Sole et al., 2007, p. 630). Suggesting that it is a relevant and dependable testing method to use in this study.

Figure 3. *Placement of stabilization straps, lever arm pad and arms in the Humac NORM isokinetic dynamometer chair (left) and hand placement during the testing sequences to minimise contribution from accessory muscles (right). Picture used with player approval.*

1.8.2 Sprint

Another relevant measurement is sprint time, as it probably is the most used testing method in interventions, including football players. Although registering the players' true sprint speed is not the focus of this study, valid and reliable measures of sprint times are critical in detecting actual change in sprint performance (Haugen et al., 2014, pp. 2376-2378). Dual-beamed photocells offer acceptable accuracy in assessing sprint times (Haugen & Buchheit, 2016, p. 653). When investigating the sprint time differences between single- and double-beamed timing systems, Haugen et al (2014) found dual-beamed to derive more accurate and reliable sprint times results than single-beamed (Bias: ± 0.06 s) (Haugen et al., 2014, p. 2378). Acceptable construct validity and high intraday and interday reliability have been found in linear-sprint tests over distances up to 40 m when assessing sprinting skills in football players (Altmann et al., 2019, p. 23). Given the importance of sprint ability in football it is variable of interest in this study.

1.8.3 Countermovement jump

The countermovement jump is one of the most used tests for monitoring neuromuscular status in individual and team sports (Claudino et al., 2017, p. 397) The propulsive action of the lower limbs during a vertical jump provides a valuable index of muscular power of the legs, which is an important determinant in many sports making valid measures of jump performance desirable (Buckthorpe et al., 2011, p. 63). Force platforms are considered the gold standard in assessing lower-limb maximal power (Castagna et al., 2013, p. 761). Portable force platforms have previously been criteria-validated against a criterion laboratory force platform (Buckthorpe et al., 2011, pp. 65-66). The results showed a strong correlation in measured jump height when comparing the portable force platform against the criterion (Bias: –0.8+3.9 cm, r = 0,97). Portable force platforms typically utilise automated software to calculate jump height and calculate jump height using the impulse-momentum method (Linthorne, 2001, p. 1201). With leg power being a significant factor related to football performance, it is relevant to assess in studies including football players.

2. References

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3. Article

Date

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Title

Prepare to fail or failing to prepare? Acute performance after FIFA 11+ with and without strength exercises

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Keywords: Warm-up; performance; strength training; football; injuries; the FIFA 11+ program

Abstract

Background: FIFA 11+ is an injury prevention warm-up program for football that includes a strength training part. Despite its proven effectiveness in reducing injuries, uncertainty remains about whether it could impair the following performance and if it should be considered an appropriate warm-up. Few studies on the acute effects of the program have been reported, with incongruent results.

Aim: To compare the acute post-exercise effects of FIFA 11+ (WU+S) and FIFA 11+ not including strength training (WU-S) on various physical performance measures.

Study design: Randomised crossover study.

Method: A total of 15 female junior football players completed WU+S and WU-S on separate days in randomised order. They were tested twice on each experimental session (pre-post warm-up) in isokinetic maximal voluntary contraction and countermovement jump. Sprint performance and RPE questionnaire were assessed post warm-up only.

Results: Players were slower on 20 and 30 m sprint after WU+S compared with WU-S ($P < 0.05$), with a tendency also observed in 10 and 40 m sprint times ($p < 0.06$ and $p < 0.052$, respectively). There was a significant difference in the change in peak torque between the two groups ($p < 0.05$). Peak torque in the WU+S group was reduced after performing the warm-up. RPE was higher after WU+S than WU-S ($p < 0.001$).

Conclusion: Performing the FIFA 11+ program as a warm-up routine with the strength training part impairs subsequent physical performance in female junior football players compared to performing the FIFA 11+ warm-up without the strength part.

Introduction

Warm-up is a generally accepted practice preceding athletic events to optimise performance (Bishop, 2003b, p. 484; McGowan et al., 2015, p. 300). Proposed mechanisms responsible for enhanced performance include an increase in muscle and tendon flexibility, muscle temperature, blood flow to the extremities and increased contractile function (Bishop, 2003a, pp. 440-443). A warm-up should be within an optimal range sufficient to elicit positive effects but not too much to cause fatigue and decrease performance (Sale, 2002, p. 138).

In the past decades, the warm-up has been targeted as a venue for injury preventive measures, and several interventions have been developed and tested. In 2006, Fédération Internationale de Football Association's (FIFA) Medical and Research Centre (F-MARC) developed the FIFA 11+ injury prevention program, a warm-up routine that consists of three parts: 1) running exercises, 2) strength, plyometrics and balance, 3) running exercises. Randomised controlled trials have proved that the program can reduce injury risk in junior football players (Soligard et al., 2008, p. 6; Steffen et al., 2013, p. 6). The injury preventive effect of the FIFA 11+ program is likely to be twofold, an acute increase in physical preparedness through the common physical acute enhancements from general warm-up and the long-term effect of the strength or proprioceptive training programme (i.e. players becoming stronger or improving their balance).

FIFA 11+ includes five strength exercises as an integral part. If one expects long-term strength adaptation, it is important that the strength volume is large enough to elicit adaptation. However, long-term adaptation from strength stimulus is expected to result from training volume where an acute fatigue response will occur. Physically demanding tasks such as strength training result in an acute decline in muscle function (Palucci Vieira et al., 2021, p. 662). One of the exercises in the program is the Nordic hamstring exercise, which has previously shown to be effective in reducing hamstring injuries among football players when performed before and after practice (Arnason et al., 2008, p. 44; Petersen et al., 2011, p. 2301; van der Horst et al., 2015, p. 1320). Given the eccentric high-intensity nature of the exercise, if performed before training, it is likely that an acute reduction in maximal hamstring force will occur before the most crucial parts of the training session begins, which can impair physical abilities related to elite performance. This reduction would be strictly opposed to the purpose of warm-ups, and unnecessary as the Nordic hamstring exercise can prevent injuries when performed before and after practice. (Small et al., 2009, p. 1081).

Therefore, this study aims to investigate whether strength training stimulus in FIFA 11+ are decreasing performance directly after completion.

Method

Study design

This study is a crossover study of Norwegian U14-U19 female football players. The study was completed during the latter part of the competitive season (November 2021). Players performed the two warm-up protocols on separate days in randomised order and tested strength, sprint and vertical jump, and were asked about RPE and readiness. Given the chosen study design, the participants served as their own matched control to compare the acute effect of FIFA 11+ with (WU+S) and without the strength training part (WU-S) on physical performance (Fig.1). The two test persons were blinded to intervention allocation for the players on both official test days. The two instructors that supervised and performed the warm-ups on test days were not blinded to player allocation. Written consent was given before enrolling (appendix 1). For players under the age of 16, written consent was also collected from a parent or guardian.
The *Norwegian Centre for Research Data* (#290192) and the *Norwegian School of Sports Sciences' Ethics Committee* (#240920) approved the study. The study was completed according to the ethical guidelines of the declaration of Helsinki.

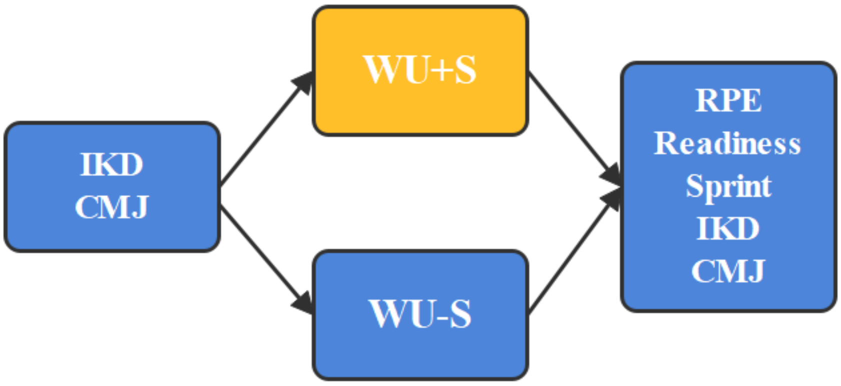

Figure 1. Design of the study and schematic view of testing day protocol and testing sequence in chronological order. IKD = isokinetic dynamometry; CMJ = countermovement jump; RPE = self-reported perceived exertion; Readiness = readiness to perform.

Participants

We recruited female football players in the age group 13-19 at the highest playing level in the Oslo-area. Twenty players, fifteen players from one team and five players from another were recruited through contacting the teams' coaches and the clubs head of development. To be eligible to participate in the study the players had to fulfil following inclusion criteria: 1) healthy female, age 13 – 19, 2) play in the highest division of their age group or play senior football in the female second division or higher, 3) no major injury two weeks prior to start-up and 4) not trained Nordic hamstring regularly through the season.

Testing procedures/outcomes

The testing and interventions were conducted at the Norwegian School of Sports Sciences and the Norwegian Olympic Training Center. All participants had one session of familiarisation before the first test day, were they performed all the tests and 5 reps of the Nordic hamstring exercise to avoid the repeated bout effect (Fig.1).

Maximal concentric knee extensor and flexor torque were tested unilaterally, right leg before left, in an isokinetic dynamometer (Humac NORM, CSMi, Stoughton, MA, USA). Players were seated with the backrest set at 85°, and the dynamometer aligned with the knee joints axis. Straps were placed on the chest, waist and thigh to minimise movement. The first test was concentric knee extension and flexion at 60°/s. Players performed four warm-up repetitions with increasing intensity before performing four repetitions with maximal effort. The same sequence was performed for 180°/s, and the series were separated with 30 s rest. Tests were performed in a ROM of 90°- 0°. We extracted peak torque, work per repetition and angle of peak torque for analysis.

Countermovement jump was measured on a portable force platform (HUR Labs, FP4, Tampere, Finland; maximal sampling frequency 1200 Hz). Players performed three jumps separated by a 30 s break, with hands on their hips and self-preferred kneeling depth. We extracted jump height, peak power, average peak power, peak force, and average peak force from the highest jump for analysis.

40 m sprint was tested on an indoor running track. Wall-mounted photocells (Athletics Training System, IC Control Media & Sport, Bromma, Sweden) placed 1 m above the ground registered time every 10 m. Players commenced each sprint in a standing position with the front foot placed 30 cm behind the first photocell. The three trials were

separated with a 1 min active break walking back. We retained sprint times for every 10 m (s) from the best trial for analysis.

A “readiness to train” and “perceived exertion” questionnaire was verbally presented to players immediately after completing the warm-up. The questionnaire consisted of two Likert-scale questions. Players were asked to answer a number ranging from 1-10 on the following two questions: 1) “On a scale from 1-10, how physically ready do you feel to perform your best if you were to complete a football training session right now?”, and 2) “On a scale from 1-10, how physically demanding did you feel the warm-up was?”.

Warm-up protocols

Table 1. FIFA 11+ warm-up protocol. WU+S performed all parts, WU-S performed only part 1 and 3.

FIFA 11+	
	Duration
Part 1: Running exercises	**8 minutes**
Straight ahead	2 sets over 30 m each exercise
Hip out	
Hip in	
Circling partner	
Shoulder contact	
Quick forwards & backwards	
Part 2: Strength	**10 minutes**
The bench: static	3 sets x 20-30 s
Sideways bench: static	3 sets x 20-30 s (each side)
Nordic hamstring: beginner	1 set x 5 repetitions
Single leg stance, hold the ball	2 sets 30 s (each leg)
Squats with toe raise	2 sets x 30 s
Vertical jumps	2 sets x 30 s
Part 3: Running exercises	**2 minutes**
Across pitch	2 sets x 30 m (75-80% max)
Bounding	2 sets x 30 m
Plant & cut	2 sets (80-90% max)

Statistical analysis

Values are expressed as mean ± standard deviation and 95% confidence intervals from pre- to post-test. All statistical analyses were completed using SPSS (SPSS version 24, IBM corporation USA). For the Humac and CMJ tests, we calculated the absolute change in the outcome variables from pre- to post-test for both warm-up protocols. The difference in change in the outcome variables between the two warm-up protocols was assessed using a paired sample t-test. For sprint and the questionnaire results attained post warm-up only, a paired sample t-test was used to compare the difference between warm-ups. An α level of 0.05 was considered significant.

Results

Of the twenty players included in the study, five players dropped out due to injury, sickness or not showing up to testing, leaving 15 players (15.7 ± 1.6 yrs, 167.4 ± 3.6 cm, 59.8 ± 6.2 kg) qualified for analysis.

Sprint performance

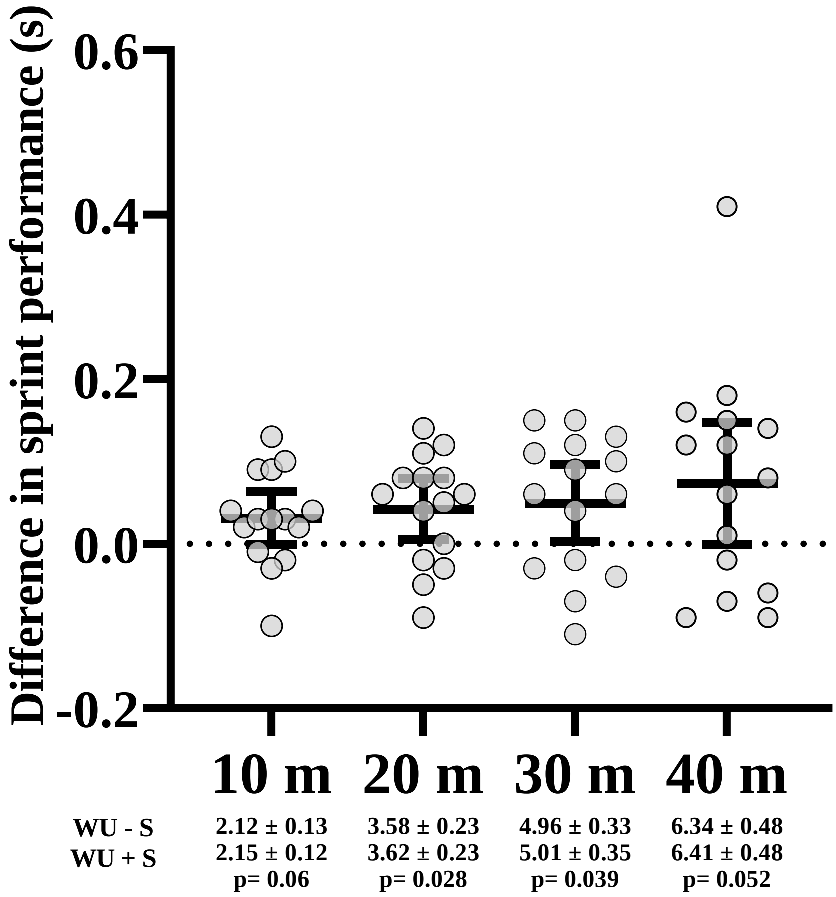

Figure 2. Absolute differences in sprint times comparing WU+S to WU-S. Positive value means WU-S was better than WU+S. Results are presented as mean, 95% CI and SD. *Significant difference between warm-up protocols (p < 0.05).

Significant difference in favour of WU-S was observed at 20 m and 30 m sprint times ($p < 0.05$) (Fig. 2). Although not reaching the level of significance, a tendency in favour of WU-S was seen in the acceleration phase (i.e., the first 10 m of the 40 m sprint) ($p = 0.06$). Moreover, a strong tendency was also observed at the 40 m sprint time ($p = 0.052$).

Isokinetic strength

Out of the six variables tested on the knee flexors, one was significantly different. There was a significant difference in the change in hamstring peak torque at 180˚/s between the two groups ($p < 0.05$), with changes favouring the WU-S (Table 2).

Changes in quadriceps work per repetition at 180˚/s also favoured WU-S, with a significant difference in the change between the two groups ($p < 0.05$) (Table 2). No difference was observed in the other five variables.

Countermovement jump

No significant differences between warm-up protocols were observed in any outcome measurements in the countermovement jump test (Table 2).

RPE and readiness questionnaire

There was a significant difference in players subjective rating of perceived exertion after the warm-ups, with players perceiving WU+S more draining ($p < 0.001$). No difference was noted in players readiness to train after the warm-ups ($p > 0.05$).

Table 2. Mean difference in pre-test and post-tests for peak torque, angel of peak torque, work and CMJ measurements.

	WU+S			WU-S			
	Pre-test	**Post-test**	**Mean diff (CI)**	**Pre-test**	**Post-test**	**Mean diff (CI)**	**P value**
PT							
60°/s Q	134 ± 26	134 ± 31	0 (-6 to 6)	137 ± 28	137 ± 28	-1 (-5 to 4)	0.82
60°/s H	100 ± 16	95 ± 17	- 5 (-8 to -2)	99 ± 17	96 ± 18	-3 (-5 to 0)	0.17
180°/s Q	91 ± 19	89 ± 17	-2 (-5 to 0)	91 ± 17	91 ± 17	0 (-3 to 4)	0.23
180°/s H	76 ± 13	73 ± 12	-3 (-4 to -1)	75 ± 13	74 ± 14	-1 (-2 to 2)	0.034*
PTA							
60°/s Q	50 ± 7	51 ± 7	2 (-1 to 4)	48 ± 6	51 ± 6	3 (1 to 4)	0.41
60°/s H	24 ± 3	23 ± 3	-1 (-2 to 1)	25 ± 4	25 ± 4	0 (-2 to 2)	0.51
180°/s Q	48 ± 5	50 ± 7	2 (-1 to 6)	47 ± 6	48 ± 5	1 (-1 to 3)	0.39
180°/s H	36 ± 4	36 ± 4	0 (-2 to 2)	36 ± 4	35 ± 4	-1 (-3 to 1)	0.35
WORK							
60°/s Q	149 ± 29	144 ± 31	-6 (-10 to -2)	150 ± 27	150 ± 27	-1 (-5 to 4)	0.13
60°/s H	112 ± 19	104 ± 19	-8 (-11 to -4)	110 ± 18	105 ± 19	-5 (-9 to – 2)	0.35
180°/s Q	97 ± 20	91 ± 19	-6 (-9 to -3)	96 ± 17	96 ± 17	0 (-4 to 4)	0.019*
180°/s H	81 ± 14	77 ± 13	-3 (-5 to -1)	80 ± 13	79 ± 15	-1 (-3 to 1)	0.10
CMJ (N= 14)							
Height (cm)	26.8 ± 4.1	27.0 ± 4.3	0.3 (0.3 to 0.8)	26.9 ± 4.2	26.9 ± 4.0	0.1 (-0.6 to 0.8)	0.68
PP	2288 ± 419	2274 ± 437	-14 (-70 to 42)	2291 ± 467	2301 ± 416	15 (-54 to 84)	0.55
Average PP	2258 ± 411	2256 ± 432	-2 (-42 to 39)	2270 ± 474	2274 ± 418	4 (-49 to 56)	0.89
PF	1247 ± 202	1209 ± 199	-38 (-80 to 4)	1288 ± 218	1253 ± 217	-35 (-73 to 4)	0.92
Average PF	1238 ± 197	1210 ± 192	-29 (-67 to 10)	1272 ± 226	1251 ± 217	-21 (-46 to 4)	0.76

PT = peak torque; PTA = angel of peak torque; WORK = work per repetition; CMJ = countermovement jump; PP = peak power; average PP = peak power average; PF = peak force; average PF = peak force average; Mean diff = mean difference; CI = 95% confidence interval; Q = quadriceps; H = hamstrings.

*Significant differences from pre-test to post-test between warm-up protocol ($p < 0.05$). ǂ CMJ (N=14) = 1 player lost due to measurement error.

Discussion

The main findings are that performing the strength part of FIFA 11+ negatively affect sprint performance and strength in female junior football players compared with performing the FIFA 11+ warm-up without the strength part.

Our results are in line with that of Ayala et al. (2017), reporting that FIFA 11+ resulted in decreased sprint performance compared to dynamic warm-up (Ayala et al., 2017). The decreased sprint performance and the decrease in peak torque in the knee flexors may be due to the eccentric Nordic hamstring exercise. Several studies have reported a selective damaging of type II muscle fibres after eccentric muscle actions, which are the most critical fibres in sprint performance (Byrne et al., 2004; Jones et al., 1997; Ross & Leveritt, 2001). These fibres may have been instantaneously fatigued, resulting in reduced ATP turnover via decreased phosphocreatine utilisation and muscle glycogen resynthesis. Conversely, Bizzini et al. (2013) and Robles Palazón et al. (2016) observed sprint changes favouring FIFA 11+ compared to a control period and a “regular warm-up”, respectively.

We observed no significant difference in the CMJ test in the current study, which is in line with a previous study comparing FIFA 11+ with a dynamic warm-up (Vazini Taher & Parnow, 2017). Our findings do not agree with Bizzini et al. (2013), reporting that FIFA 11+ elicits significant improvements in CMJ jump height (Bizzini et al., 2013). Our results may be explained by many of the players still developing, both in physical maturation and skills. Adolescent female players demonstrate movement pattern characteristics with neuromuscular deficits attributed to a lack of strength, power, and motor control and coordination (DeLang et al., 2021; Hewett et al., 2004; Myer et al., 2005; Myer et al., 2013). Players might not have been able to exploit their true force potential, affecting the ability to differentiate between each test.

The RPE results are in line with Chen et al. (2019), with a significantly higher RPE score after completing FIFA 11+ compared to a dynamic warm-up routine (Chen et al., 2019). Our results are likely due to the strength training component of the program, as it is the only differentiating factor. However, there was no difference in readiness to perform. This discrepancy may be due to player mentality and players thinking they should be ready to play following a warm-up as is expected.

The implications of the menstrual cycle should be noted, with different menstrual phases observed to affect anaerobic performance adversely and elicit fatigue (Carmichael et al., 2021; Elliott-Sale et al., 2020; McNulty et al., 2020; Meignié et al., 2021). Variations in players daily form is an important aspect to consider with numerous factors playing a part in players daily psychological and physiological function (Nédélec et al., 2015; Nedelec et al., 2012). Given the sample size in our study its feasible this may be a factor affecting the results.

Limitations

Due to a scheduling conflict with the Norwegian School of Sport Sciences, we used two different HUMAC dynamometers (but of the same model) in the project. The Humac NORM isokinetic dynamometer offers excellent intrarater reliability for the knee extensors and flexors; intraclass correlation coefficient: 0.82 (0.74-0.89), standard error of measurement range: 13-23.1% (Habets et al., 2018). Therefore, we consider it unlikely that this would significantly affect the strength results.

The scheduling conflict caused approximately 5 minutes delay from sprint to isokinetic and CMJ. Post-activation potential acutely enhances muscular performance and is reported to dissipate after 1-8 min (Kilduff et al., 2008; Macintosh et al., 2012). We might have missed the potentiating effect of either warm-up on the isokinetic and CMJ test. However, potentiated effects after warm-up routines have mainly been found after ballistic and weight-based exercises (Creekmur et al., 2017; Turner et al., 2015; Weber et al., 2008). Due to the lack of such components in the FIFA 11+ program and the reduced sprint performance observed, we find it unlikely to have missed any potentiating effect.

The delay might have been sufficient time for players to recover from the warm-up. If players had enough time to recover, the isokinetic and CMJ results might not represent the actual fatiguing effect of either warm-up. Possibly other test variables would have been significantly different without the delay.

Rescheduling of games due to the Covid-19 pandemic resulted in some players performing testing at a different time of day. Physical performance can be affected by the difference in circadian rhythms, known as the time-of-day effect (Chtourou & Souissi, 2012; Drust et al., 2005). No players were tested in the morning (between 06:00

and 10:00 hours) when anaerobic performance is reported to be most affected (Chtourou & Souissi, 2012). We consider this unlikely to have affected testing.

Five players dropped out, which reduces statistical power. However, the analysed sample size was similar to those previously used in warm-up studies (Amiri-Khorasani et al., 2011; Ayala et al., 2017; Bizzini et al., 2013; Opplert & Babault, 2019).

Strengths of the current study include the experimental design, statistical analysis, familiarisation protocol, testing procedure, in-season testing, and inclusion of the program's target population.

Conclusion

The findings of this study are that performing the FIFA 11+ warm up with the strength training part impairs subsequent physical performance in female junior football players compared to when the warm-up is performed without the strength training.

Practical applications

The performance decrements in sprint performance and increased perceived rating of exertion by players after warm-up, with strength exercises found in this study, should be of interest to football coaches and physical trainers. Coaches prefer players to be physically fit and mentally present for the whole duration of training sessions to work on the team’s and individual player’s development. Players starting the session in a state of fatigue after a warm-up taking up approximately 1/3 of the session would not be the preferred choice, as it also limits training time with the ball. Implementation of injury preventive exercises such as the Nordic hamstring should still be performed as the absence of injuries is a significant factor in a player’s development. However, this exercise may be better performed at the end of footballing sessions as the timing of the exercise seem irrelevant and may provide further benefits than just injury prevention. Future research should focus on warm-up routines that elicit performance benefits, supplemented with a cool-down routine for injury prevention.

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ACRONYMS

ROM	Range of motion
T_m	Muscle temperature
MFCV	Muscle fibre conduction velocity
PCr	Phosphocreatine
ATP	Adenosine triphosphate
NHE	Nordic hamstring exercise
FIFA	Fédération Internationale de Football Association’s
F-MARC	FIFA Medical and Research Centre
PAP	Post-activation potentiation
WU+S	FIFA 11+
WU-S	FIFA 11+ without the strength training part
RPE	Self-reported perceived exertion
Readiness	Readiness to perform
CMJ	Countermovement jump
SD	Standard deviation

Appendix

3.1 Appendix – Declaration of consent

Vil du delta i forskningsprosjektet

Passer styrkeøvelser inn i oppvarmingen til fotball?

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å undersøke om gjeldende anbefalinger for skadeforebyggende oppvarmingsprogrammet tar vare på fotballprestasjonen. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål

Formålet med prosjektet er å undersøke om tidligere anbefalte doser av styrketrening i fotball kan være negativt for fysisk og mental prestasjonsevne. Tidligere studier har foreslått doser med styrketrening som normalt vil gi en akutt muskeltrøtthet. Med hensikt å gi styrkeeffekt over tid, som igjen vil gjøre at man kan være bedre rustet til å stå imot skader. Dette akutte kraftfallet er ikke i samsvar med oppvarmingens opprinnelige formål, å forbedre prestasjonen i påfølgende aktivitet. Derfor er formålet med denne studien å måle mentale og fysiske effekter av tidligere anbefalte oppvarmingsprogram.

Hvem er ansvarlig for forskningsprosjektet?

Norges Idrettshøgskole er ansvarlig for prosjektet.

Hvorfor får du spørsmål om å delta?

Vi inviterer seks kvinnelige juniorlag i osloområdet som spiller på den øverste divisjonen av juniorfotball. Du får denne informasjonen dersom din trener har godtatt at vi henvender oss til spillergruppen med spørsmål om dere ønsker å delta. Vi har fått kontakt til deg via din trener eller leder på laget.

Hva innebærer det for deg å delta?

Metodene i denne studien vil være fysiske tester, bevegelsesregistrering, samt spørreskjemaer rundt din oppfattelse av fysisk anstrengelse og restitusjon. Data som blir samlet inn er utelukkende fra disse tre kildene.

- «Hvis du velger å delta i prosjektet, innebærer det at du møter opp ved seks anledninger der tre av oppmøtene er tilvenningsdager, mens de tre andre er testdager. Ved alle dagene vil du bli testet i fysiske tester som måler din kraftutvikling i strekkapparatet i beina. I tillegg vil du måtte besvare et spørreskjema bestående av to spørsmål ved to anledninger per oppmøte. Oppmøte 1 og 2 vil ta rundt 30 minutter, oppmøte 3 ca 15minutter, mens de tre siste (testdagene) vil ta ca. 45 minutter.

Hvis personer under 16 år deltar, kan foreldre få se spørreskjema/intervjuguide etc. på forhånd ved å ta kontakt.

Det er frivillig å delta

Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykket tilbake uten å oppgi noen grunn. Alle dine personopplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger
Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.

- Kun prosjektansvarlig og dataansvarlig vil ha tilgang til opplysningene om deg (navn og fødselsdato).
- Navnet og kontaktopplysningene dine vil erstattes med en kode som lagres på egen navneliste adskilt fra øvrige data. All data blir lagret på sikker forskningsserver.

Ingen av deltagerne vil kunne bli gjenkjent i publikasjoner.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?
Opplysningene anonymiseres når prosjektet avsluttes/oppgaven er godkjent, noe som etter planen er 01.10.2025 Alle personopplysninger vil slettes/destrueres senest ved dette tidspunkt (navn/fødselsdato fra samtykkeskjema). All data er ikke-identifiserbar.

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke personopplysninger som er registrert om deg, og å få utlevert en kopi av opplysningene,
- å få rettet personopplysninger om deg,
- å få slettet personopplysninger om deg, og
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra Norges Idrettshøgskole har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Hvor kan jeg finne ut mer?
Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:

- Torstein Dalen-Lorentsen, Norges idrettshøgksole (torstein.dalen@nih.no) eller Merete Møller (meretem@nih.no).
- Vårt personvernombud: Karine Justad, +4797536704. Karine.justad@nih.no
-

Hvis du har spørsmål knyttet til NSD sin vurdering av prosjektet, kan du ta kontakt med:

- NSD – Norsk senter for forskningsdata AS på epost (personverntjenester@nsd.no) eller på telefon: 55 58 21 17.

Med vennlig hilsen

Merete Møller & Torstein Dalen
(Forsker/veileder) (Stipendiat)

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet «Passer styrkeøvelser inn i oppvarmingen til fotball?», og har fått anledning til å stille spørsmål. Jeg samtykker til:

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet

- ☐ Til å delta i prosjektet («Passer styrkeøvelser inn i oppvarmingen til fotball?»

(Signert av prosjektdeltaker, dato)

3.2 Appendix – Approval from the Norwegian Centre of Research Data

NSD NORSK SENTER FOR FORSKNINGSDATA

Meldeskjema 290192

Sist oppdatert

10.09.2020

Hvilke personopplysninger skal du behandle?

- Navn (også ved signatur/samtykke)
- Fødselsdato

Type opplysninger

Skal du behandle særlige kategorier personopplysninger eller personopplysninger om straffedommer eller lovovertredelser?

Nei

Prosjektinformasjon

Prosjekttittel

Prepare to fail or failing to prepare? Strength training's role in team sport warm-up

Begrunn behovet for å behandle personopplysningene

Vi trenger fødselsdato for å regne ut gjennomsnittlig alder på deltagerne for å kunne beskrive utvalget. Navn trenger vi ikke, men de vil signere på samtykke med sitt navn og det vil på den måten bli synlig for oss.

Ekstern finansiering

Type prosjekt

Forskerprosjekt

Behandlingsansvar

Behandlingsansvarlig institusjon

Norges idrettshøgskole / Institutt for idrettsmedisinske fag

Prosjektansvarlig (vitenskapelig ansatt/veileder eller stipendiat)

Torstein Dalen-Lorentsen, torstein.dalen@nih.no, tlf: 93841844

Skal behandlingsansvaret deles med andre institusjoner (felles behandlingsansvarlige)?

Nei

Utvalg 1

Beskriv utvalget

Fotballspillere i alder 15-19år

Rekruttering eller trekking av utvalget

Vi vil gå ut bredt og søke etter ett eller to lag og vil ta med de to første som aksepterer.

Alder

15 - 20

Inngår det voksne (18 år +) i utvalget som ikke kan samtykke selv?

Nei

Personopplysninger for utvalg 1

- Navn (også ved signatur/samtykke)
- Fødselsdato

Hvordan samler du inn data fra utvalg 1?

Papirbasert spørreskjema

Grunnlag for å behandle alminnelige kategorier av personopplysninger

Samtykke (art. 6 nr. 1 bokstav a)

Hvem samtykker for barn under 16 år?

Foreldre/foresatte

Hvem samtykker for ungdom 16 og 17 år?

Ungdom

Felteksperiment/feltintervensjon

Grunnlag for å behandle alminnelige kategorier av personopplysninger

Samtykke (art. 6 nr. 1 bokstav a)

Hvem samtykker for ungdom 16 og 17 år?

Ungdom

Informasjon for utvalg 1

Informerer du utvalget om behandlingen av opplysningene?

Ja

Hvordan?

Skriftlig informasjon (papir eller elektronisk)

Tredjepersoner

Skal du behandle personopplysninger om tredjepersoner?

Nei

Dokumentasjon

Hvordan dokumenteres samtykkene?

- Elektronisk (e-post, e-skjema, digital signatur)

Hvordan kan samtykket trekkes tilbake?

Ved henvendelse til prosjektmedarbeider

Hvordan kan de registrerte få innsyn, rettet eller slettet opplysninger om seg selv?

Ved kontakt til prosjektleder (som de får kontaktinformasjon til i samtykkeskjema)

Totalt antall registrerte i prosjektet

1-99

Tillatelser

Skal du innhente følgende godkjenninger eller tillatelser for prosjektet?

- Godkjenning fra egen ledelse til intern kvalitetssikring (helsepersonelloven § 26)

Behandling

Hvor behandles opplysningene?

- Maskinvare tilhørende behandlingsansvarlig institusjon

Hvem behandler/har tilgang til opplysningene?

- Prosjektansvarlig

Tilgjengeliggjøres opplysningene utenfor EU/EØS til en tredjestat eller internasjonal organisasjon?

Nei

Sikkerhet

Oppbevares personopplysningene atskilt fra øvrige data (kodenøkkel)?

Ja

Hvilke tekniske og fysiske tiltak sikrer personopplysningene?

- Opplysningene anonymiseres
- Adgangsbegrensning

Varighet

Prosjektperiode

01.10.2020 - 01.10.2025

Skal data med personopplysninger oppbevares utover prosjektperioden?

Nei, data vil bli oppbevart uten personopplysninger (anonymisering)

Hvilke anonymiseringstiltak vil bli foretatt?

- Koblingsnøkkelen slettes
- Personidentifiserbare opplysninger fjernes, omskrives eller grovkategoriseres
- Lyd- eller bildeopptak slettes

Vil de registrerte kunne identifiseres (direkte eller indirekte) i oppgave/avhandling/øvrige publikasjoner fra prosjektet?

Nei

Tilleggsopplysninger

3.3 Appendix – Approval from the ethics committee, Norwegian School of Sport Sciences

Merete Møller
Institutt for idrettsmedisinske fag

OSLO 25. september 2020

Søknad 158 – 240920 – Styrketrenings rolle i oppvarming i ballspill

Vi viser til søknad, prosjektbeskrivelse, informasjonsskriv, spørreskjema og innsendt melding til NSD.

I henhold til retningslinjer for behandling av søknad til etisk komite for idrettsvitenskapelig forskning på mennesker, ble det i komiteens møte av 24.september 2020 konkludert med følgende:

Vurdering

I søknaden fremgår det at formålet med prosjektet er å undersøke om tidligere anbefalte doser av styrketrening i fotball kan være negativt for fysisk og mental prestasjonsevne. Komiteen vil bemerke at spørreskjemaet inneholder spørsmål om selvrapportert mental utmattelse, ikke om mental prestasjonsevne som krever mer omfattende informasjon. Dersom dette skjemaet skal benyttes, ber komiteen om at prosjektplanen og informasjonsskrivene oppdateres mht hva som skal undersøkes. Da det skal samles inn data fra fysiske tester som inngår i særlige kategorier av personopplysninger (helseopplysninger), skal foresatte samtykke for deltakere under 16 år. (Ref Datatilsynets og NSDs retningslinjer for samtykke). Komiteen ber derfor om at det utarbeides et informasjonsskriv til foresatte for forskningsdeltakerne som er under 16 år.

Vedtak

På bakgrunn av forelagte dokumentasjon finner komiteen at prosjektet er forsvarlig og at det kan gjennomføres innenfor rammene av anerkjente etiske forskningsetiske normer nedfelt i NIHs retningslinjer. Til vedtaket har komiteen lagt følgende forutsetning til grunn:

- *Vilkår fra NSD følges*
- *Oppdatert prosjektplan og informasjonsskriv sendes komiteen til orientering*
- *Informasjonsskriv til foresatte for deltakere under 16 år utarbeides*

NIH NORGES IDRETTSHØGSKOLE

Besøksadresse: Sognsveien 220, Oslo
Postadresse: Pb 4014 Ullevål Stadion, 0806 Oslo
Telefon: +47 23 26 20 00, postmottak@nih.no
www.nih.no

Komiteen gjør oppmerksom på at vedtaket er avgrenset i tråd med fremlagte dokumentasjon. Dersom det gjøres vesentlige endringer i prosjektet som kan ha betydning for deltakernes helse og sikkerhet, skal dette legges fram for komiteen før eventuelle endringer kan iverksettes.

Komiteen forutsetter videre at prosjektet gjennomføres på en forsvarlig måte i tråd med de til enhver tid gjeldende tiltak ifbm Covid-19 pandemien.

Med vennlig hilsen

Sigmund Loland

Professor Sigmund Loland
Leder, Etisk komite, Norges idrettshøgskole

NORGES IDRETTSHØGSKOLE

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