Title: **Part 2 of the 11+ as an effective home-based exercise programme in elite academy football (soccer) players: a one-club matched-paired randomised controlled trial**

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ABSTRACT

Although the 11+ is known to reduce injuries and improve performance in adolescent footballers, its duration presents a notable barrier to implementation. Hence, this study investigated injury and performance outcomes when 65 elite male academy footballers either performed Part 2 3x / week at training (TG) or at home (HG). Time to stabilisation (TTS), eccentric hamstring strength (EH-S) and countermovement jump height (CMJ-H) were collected four times during the 2019 football season. Linear mixed-models were used to evaluate main and interaction effects of group and time. Bonferroni post-hoc tests were used to account for multiple comparisons. Differences in time loss and medical attention injuries were determined using a 2-tailed Z test for a comparison of rates. Relative to baseline, EH-S (HG 4.3 kg, 95% CI 3 to 5.7, $p < 0.001$; TG 5.5 kg, 95% CI 4.3 to 6.6, $p < 0.001$) and CMJ-H (HG 3.5 cm, 95% CI 2.2 to 4.7, $p < 0.001$; TG 3.2 cm, 95% CI 2.2 to 4.3, $p < 0.001$) increased, with no difference between groups observed at the end of the season. All injury outcomes were similar. Hence, rescheduling Part 2 did not affect performance or increased injury risks in academy footballers.

Key Words

Football, soccer, FIFA 11+, 11+, injury prevention, adolescence

INTRODUCTION

Around the time of peak height velocity, the risk of injury for an adolescent athlete may be increased.[1, 2] Growth related gains in muscle volume and increased tendon stiffness[3] occur while bone tissue and growth plates are still vulnerable,[4] hence intensified stress on tendon attachment areas can lead to lower limb overuse injuries in adolescent footballers.[5] The 11+, a warm-up programme consisting of running-based (Part 1 and 3), strength, power and neuromuscular control exercises (Part 2), was designed to reduce non-contact lower limb injuries in adult footballers[6] and has also been proven effective in players as young as 14 years, reducing lower limb injury by 48% and overuse injuries by 74%.[7] Additionally, the 11+ exercises also improve power, agility and short-distance sprinting in adolescent male footballers.[8, 9] Importantly, it is also evident that performing these exercises more frequently improves physical adaptation[10] at the same time as reducing injury rates and severity.[11, 12] However, low programme compliance is frequently observed.[11, 13]

Common barriers to programme implementation and adoption include the time required to complete the programme[11] and in professional youth football, this can be dependent on player motivation, communication between coaching and medical staff, game and training schedules.[14] A potential option to overcome these barriers may be to explore alternative delivery methods of the 11+ which one study to date has examined.[12] In this study, moving Part 2 of the 11+ to the end of training resulted in 35% higher compliance with similar reductions in injury rates, lower severity and burden when compared to those completing the full programme before training.[12] It thus appears as though the original structuring of the programme, that all parts are performed before training as a 'warm up', is not necessary to maintain programme efficacy. However, scheduling the exercises after training does not actually impact the total time required for programme delivery and execution during the course of a training session.

This study therefore investigates performance effects and injury rates of 'rescheduling' the 11+ by asking players to perform Part 2 at home and Parts 1 and 3 as a warm-up before training and games. It was hypothesized that these players would show similar performance changes compared to players performing all parts of the 11+ at training.

MATERIALS and METHODS

Study Design and Participant Recruitment

The study was designed as a matched-paired randomised controlled trial and the reporting follows the Consolidated Standards of Reporting Trials (CONSORT) statement when applicable[15]. Participants were recruited following convenience sampling in November 2018. Eligible participants were players between the ages of 12 and 16, registered to play for the same football club during the 2019 season. Based on previous literature, the between-group effect size calculation was expected to show a moderate to large effect ($d \geq 0.5$) between each testing session for the primary outcome measures (physical performance) when a minimum of 16 participants were allocated to each group.[16] It was expected that the number of injuries would only be sufficient to detect strong associations ($d \geq 0.8$),[17] therefore injury rates were only included as secondary outcome measure.

65 elite male academy football players (13.9 y, SD 1.2; 163.1 cm, SD 12.6; 52.2 kg, SD 11.4) from the U13 (n = 23), U14 (n=18), U15 (n=12) and U16 (n=12) teams volunteered to participate and all players and their parents/guardians provided signed informed consent. The University Ethics Committee approved the project (2018/445) which took place at the football club's training centre in Sydney, Australia.

Players were stratified according to age, known previous injury history (severity and type of time-loss injuries) and baseline hamstring strength. Matched pairs were then assigned to a training group (TG) or home group (HG) (Figure 1) using a computer-generated random number generation. The researchers, intervention deliverers and participants were not blinded. The TG (n=32, 13.9 y, SD 1.2; 163.5 cm, SD 12.2; 52.4 kg, SD 11) performed Part 2 of the 11+ at the end of training (3 × / week),[12] the HG (n=33, 13.9 y, SD 1.2; 162.8 cm, SD 13.2; 51.9 kg, SD 11.9) completed Part 2 at home (3 × / week). Both groups performed Part 1 and 3 before training (3 × / week) and games (1 × / week). The TG Part 2 exercise compliance was not monitored but was considered a normal component of the training session for these players. The HG completed a weekly online survey (via SurveyMonkey) to document the frequency and completion rate of exercises performed. If exercises were missed, players were asked: "Did you experience any issues with the exercises?", "Which exercises did you leave out?" and "How many times did you miss these exercises out?".

INSERT FIGURE 1 HERE

11+ implementation

Figure 2 outlines the experimental design. As the exercises in Part 2 progress from Level 1 to Level 3, within each level there is a prescription range for certain exercises, for example 3 to 5 repetitions or 20 to 30 seconds. In this study, 'Beginner' refers to when the lower number of repetitions and duration (e.g., 3 repetitions and 20 seconds) are performed and refers to 'Advanced' when a higher number of repetitions and time period was prescribed (e.g., 5 repetitions and 30 seconds) (Table 1, supplementary material). All players were familiarised with the 11+ exercises, performing Parts 1 and 3 before training and Part 2 (Level 1: Advanced) after training during the nine-week pre-season, which included a three-week break (weeks 6 – 8) from club football due to a scheduled Christmas break. In week 10, all players were familiarised with Level 2 (Beginner) and performed the exercises after training. From week 11, players were assigned to HG or TG for the remainder of the season (33 weeks). During the first week of each phase of exercise progression, Level 2 (Advanced) and Level 3 (Beginner), the exercises were completed by both groups for one week at training to ensure familiarisation and correct technique. Then, for the remaining 9 – 11 weeks of each phase, players performed Part 2 within their designated group. Six sports and exercise science students were instructed and trained to familiarise all players and to deliver the 11+ to the TG group throughout the season. All players were considered ready to progress to the next level at each stage following assessment by the lead researcher, a member of the medical team (SV). The Copenhagen exercise was added at the request of the club's medical staff to Part 2 of the 11+ as an eccentric hip adduction strengthening exercise from week 1 and was included in Part 2 for both HG and TG[16]. Baseline testing took place at the end of week 9, testing in weeks 23, 35 and 45 was performed on the first training day of the week.

INSERT FIGURE 2 HERE

Performance data collection

The countermovement jump and time to stabilisation tests selected in this study have been used in previous research evaluating 11+ effectiveness on jump performance[9] and balance[18]. Investigating knee flexor strength with the eccentric hamstring strength test was chosen as the 11+ includes the Nordic Hamstring exercise which has been shown to improve strength and sprint performance in footballers[19-21]. The tests used in this study have all been shown to be reliable.[22-24]

First, standing height (Charder stadiometer, HM 200P, Taiwan) and body mass (Polar Balance Scales, 1G, Finland) were recorded to the nearest 0.1 cm and 0.1 kg, respectively. Leg length was measured to the nearest 0.1 cm with a dressmakers tape from the ASIS to the medial malleolus of the tibia of the preferred kicking leg.[23] A five-minute warm-up on a stationary bike was then performed at a self-selected moderate intensity before completing the following tests in order.

Time to stabilisation (balance)

Time to stabilisation (TTS) was assessed using a 1000 Hz piezoelectric force platform (Kistler Instruments Pty Ltd, portable platform 9260AA6, Australia). Players were instructed to stand in a neutral position with hands on hips and toes touching a marked line set to a distance equal to the player's leg length from the centre of the force platform.[23] The player was instructed to jump from a double leg stance onto the centre of the force platform, land on a single limb and maintain this position for 15 seconds. Players performed the test twice on each (alternating) leg. The force platforms software (BioWare, version 5.3.2.9) recorded the antero-posterior, medial-lateral and vertical ground reaction force. Time to stabilisation was calculated using a custom-written Matlab script (R2019b), which computed the time taken from ground contact (when vertical force first exceeded 10 N) to the first point when the vertical force component reached and stayed within 5% of the player's body weight for one second.[25]

Countermovement jump height (lower limb power)

Players were asked to stand in the middle of a jump mat (Smart Jump, Fusion Sport, Australia) in a neutral position with hands on hips throughout the test, then instructed to squat to a self-selected depth, jump as high as possible, extending the knees in the air before landing.[26] Each player was permitted as many trial sub-maximal attempts as desired. Jump height (cm) was recorded during two maximal trials separated by two minutes of rest.[26] During test 1, countermovement jump height (CMJ-H) could not be measured due to technical issues, however players performed the jumps to maintain similar physical demands across all testing sessions.

Eccentric hamstring strength (strength)

Eccentric hamstring strength (EH-S) was assessed using fixed frame dynamometry (KangaTech, MFC 05178234/5, 2016, Australia). Participants were instructed to kneel on the device's padded board in an upright position with ankle braces positioned proximal to the lateral malleolus and lower the upper body slowly forward whilst maintaining the hip and back in line with the shoulders. Once the movement could not be controlled, the player dropped the upper body and hips onto the padded board, using the hands to break the fall.[27] After a warm-up of three sub-maximal efforts and subsequent one-minute rest, two maximal efforts with two minutes rest between each effort were performed. Force output was recorded in kg.

Height and body mass data collection

Standing height and body mass were collected before training once / month to calculate monthly height (rate of growth, ROG) and weight gains (rate of body mass, ROB).

Injury data collection

The club's academy physiotherapist and chief investigator (SV) recorded injuries and individual training and match exposure during pre- and in-season (week 1 – week 44). Time-loss (TL) injuries were defined as "an injury that results in a player being *unable* to take a *full* part in future football training or match play" and collected according to the Football Consensus Statement.[28] Medical attention (MA) injuries defined as 'any physical complaint reported to the academy physiotherapist requiring medical attention while allowing the player to *continue full* training or match play', were also recorded with the reporting date of injury set as day-1 and final day as the date of the first complaint-free session.[29]

Statistical Analysis

A Shapiro Wilk test (*R*, version 3.6.2, R Foundation for Statistical Computing, Vienna, Austria; *stats* package) was performed to check for normality. Height and body mass over time were compared between groups using linear mixed-models and Bonferroni multiple comparisons tests (*lme4* package[30]). Linear mixed models evaluated main and interaction effects of group and time for EH-S, CMJ-H and TTS by including test number and group as fixed effects and player as random effects. ROG and ROB were included as covariates in separate models (due to collinearity issues between these variables) to assess and correct for performance changes due to progress in height or body mass.[31] These covariates were retained in the model when statistical significance and an improved model fit (R^2) was observed. Bonferroni post-hoc tests were applied to account for multiple comparisons where significance was observed. TL injury burden was calculated as the number of days lost per 1000 hours of exposure.[32] The number of days impacted by a MA injury were calculated per player and averaged per group. Injury incidence was calculated as the total (TL + MA) number of all injuries / total (training + match) football exposure (h) x 1000 h. Between group differences in injury incidence, burden and days affected by MA injury were examined using a 2-tailed Z test (*DescTools* package) for a comparison of rates. Significance was set at p <0.05 and data are described as mean with 95% confidence interval (CI).

RESULTS

All data except age was normally distributed. No between groups differences were observed in age, height and mass at baseline. Height (p < 0.001) and body mass (p < 0.001) increased in both groups over the season with no difference in ROG or ROB between groups at any time (Table 1).

INSERT TABLE 1 HERE

CMJ-H improvements were observed relative to baseline at test 3 (HG 3.5 cm, CI 2.2 to 4.7, p < 0.001; TG 3.2 cm, CI 2.2 to 4.3, p < 0.001) and between test 2 and 3 (HG 3.1 cm, CI 1.8 to 4.3, p < 0.001; TG 2.3 cm, CI 1.3 to 3.4, p = 0.001) (Figure 3). No between-group differences were observed. ROG impacted upon the statistical model assessing EH-S (p = 0.016) and was therefore included as a covariate in the analysis. Relative to baseline, EH-S gains were observed at test 1 (HG 2.5 kg, CI 1.4 to

3.6, $p = 0.001$; TG 4.1 kg, CI 3 to 5.2, $p < 0.001$), test 2 (HG 3.8 kg, CI 2.7 to 4.9, $p < 0.001$; TG 5.2 kg, CI 4 to 6.3, $p < 0.001$) and test 3 (HG 4.3 kg, CI 3 to 5.7, $p < 0.001$; TG 5.5 kg, CI 4.3 to 6.6, $p < 0.001$) (Figure 4). A significant group × time interaction was evident at test 1 (1.6 kg, CI 0.1 to 3.2, $p = 0.036$), and a significant increase between tests 1 and 3 was observed only in the HG (1.9 kg, CI 0.5 to 3.3, $p = 0.044$). No significant change was observed in TTS at any time.

INSERT FIGURE 3 HERE

INSERT FIGURE 4 HERE

Injury incidence, injury burden and days affected by MA injury were similar in TG and HG (Table 2) with no statistical difference between groups. HG dose exposures were reported as 2.8 (CI 2.7 to 2.9) × / week, with all exercises performed 87% of the time. Having no partner (48.9%) and injury / soreness / sickness (44.7%) were reported as the main reasons for not fully completing the programme. Copenhagen and hamstring exercises were reported as most often 'missed' (29% and 28% respectively). (Compliance data can be found in Table 2 of the supplementary material.)

INSERT TABLE 2 HERE

DISCUSSION

For the first time, the present study provides evidence to show that male elite academy footballers can complete Part 2 of the 11+ programme outside of the training environment without compromising important physical performance adaptions for eccentric hamstring strength and lower limb power.

Specifically, EH-S and CMJ-H improved regardless of performing Part 2 at home or supervised at training. Although the data can only be considered preliminary due to the low number of injuries observed, the results suggest that rescheduling Part 2 does not increase injury risks, as no difference in injury incidence or burden was observed between groups.

Eccentric hamstring strength

EH-S increased significantly in both groups over the course of the season, with the greatest improvements in EH-S observed in the first 13 weeks of the experimental intervention. Herein, ROG and ROB were examined and included where significance was observed in between group analysis to normalise for changes in growth or body mass.[8, 33] However, in contrast to previous research highlighting EH-S gains in youth footballers almost exclusively within the first four to six weeks of Nordic hamstring training,[19, 34] the gains observed in this study occurred after a nine week familiarisation period. The progressive increase in exercise loading over the whole season in the current study compared to a four week period[19] may thus have continued to stimulate neural adaptations in subjects accustomed to exercise[35] and structural adaptions such as increases in the muscle's physiological cross-sectional area and fascicle length.[36, 37] Interestingly, the EH-S gains observed in the TG were greater than the HG during the initial 13 weeks of the intervention. It is possible that the HG may have increased hamstring strength via greater structural adaptation due to additional metabolic fatigue and increased mechanical tension when completing the eccentric hamstring exercise directly after football training.[38] The HG however showed a significant increase in strength from test 1 to test 3 (1.9 kg in the HG compared to 1.4 kg in the TG) such that the total EH-S gain between groups was similar over the course of the season. This suggests that during the initial phase of a season, the 11+ hamstring exercise could be performed after training and then transitioned to be completed at home to maximise strength gains, which has been associated with reduced injury risk.[39]

Countermovement jump height

Increases in CMJ-H were not evident in the current study until the final testing session (week 45), however the overall improvements were similar to previous reports in youths performing the 11+ throughout a football season.[8] It is possible that neural adaptations during the familiarisation period prior to baseline testing may have occurred, dampening any of the measured effects during the initial part of the season. This cannot be confirmed, though, as no pre-familiarisation testing took place. Of note, lateral jumps (Part 2, Level 2) performed between baseline testing and test 2 likely did not induce specific adaptations measured by the countermovement jump test,[40] compared to box jumps (Part 2, Level 3), which were performed between testing sessions 2 and 3.[41] Our results may therefore question whether the 11+ jumping exercises may need to be changed if the aim is to improve vertical lower limb power. Lateral jumps may be better suited as a balance exercise progression as the impact on reducing injuries due to improved knee stability during single-leg landing,[42] especially during physical maturation,[43] should not be disregarded.

Time to stabilisation

No improvement in knee and ankle stability during single-leg landing assessed via TTS[44] were observed in TG or HG. Neurological development, changes in the proprioceptive system and physical growth due to maturation might have influenced the results found in this study.[45] Previously, balance improvements have been observed in similar aged football players following injury prevention programmes.[46] However, with regards to balance performance, a larger cohort of elite players performing the 11+ regularly has not been investigated to date. Therefore, it may be considered that the 11+ exercises may be insufficient to improve balance in elite adolescent players, and that more advanced exercises may be required.[14] Future research including more tests investigating the effects of the 11+ exercises on balance is required.

Strengths and limitations

A key feature of this intervention's success is likely a consequence of the high compliance rate of the HG which was close to 3 × / week with individual exercises only missed 13% of the time. Moreover, assessments of strength, power and balance were included to draw conclusions on programme effectiveness,[22-24] given that the number of injuries alone were considered insufficient.[17] Similar injury rates likely reflect the comparable improvements observed across the exercise assessments in HG and TG, however further research is required to investigate the true injury reduction effects in elite adolescent footballers when Part 2 of the 11+ is performed at home. As no control group was included, this research cannot confirm an injury reduction effect per se, and no clear conclusions can be drawn on the magnitude of change regarding any performance outcome. Additionally, TG players were instructed not to perform additional 11+ exercises at home, however this was not monitored and cannot be excluded. Moreover, no intra-subject reliability testing was performed, and no testing was performed prior to baseline testing. But whilst any differences between groups at this stage may have been attenuated by the extended familiarisation period, the three-week break (weeks 6 – 8) likely minimised these effects.[47] Furthermore, peak height velocity estimates may have been more appropriate as covariates than ROG or ROB, however there were insufficient seated height measurements in the data set. Finally, exercise exposure of the TG was not collected on an individual player level to provide better comparison to the HG due to time restrictions. The trial protocol was not pre-registered but can be accessed via the ethics application (2018/445) approved by the UOW & ISLHD Health and Medical Human Research Ethics Committee. No harms or unintended effects were reported.

Practical implications

Although the 11+ has shown to increase performance parameters[8, 9] and decrease injuries[7] in adolescent footballers, time availability at training remains one of the major barriers to programme implementation.[11] This study shows that rescheduling Part 2 of the 11+ programme outside of the training environment elicits similar performance improvements without effecting injury rates negatively and can therefore be recommended in adolescent male elite footballers to maintain player availability and participation in training and games. Such rescheduling directly reduces the time required to complete a season-long injury reduction programme at training and may increase programme adoption.

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Disclosure Statement

No potential conflict of interest was reported by the authors.

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STATEMENTS

Data availability statement

Data are available from the authors upon reasonable request.

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TABLES

Table 1:

Table 1: Height and body mass changes of players in the home group (HG) and training group (TG).

Time period	All (n = 65)	HG (n = 32)	TG (n = 33)
	Height (cm) Mean (95% CI)	**Rate of growth (cm)** Mean (95% CI)	
Nov – Jan	162.88 (159.73 to 166.02)	1.21 (0.96 to 1.45)	1.13 (0.88 to 1.38)
Jan – Apr	164.65 (161.57 to 167.73) *	1.78 (1.46 to 2.11)	1.58 (1.23 to 1.93)
Apr – Jul	166.40 (163.28 to 169.51) **	1.68 (1.38 to 1.99)	1.85 (1.57 to 2.12)
Jul – Sept	165.25 (161.79 to 168.70) **	0.73 (0.47 to 0.98)	0.67 (0.36 to 0.98)
	Body mass (kg) Mean (95% CI)	**Rate of body mass (kg)** Mean (95% CI)	
Nov – Jan	51.88 (49.05 to 54.70)	1.57 (1.01 to 2.13)	1.17 (0.81 to 1.54)
Jan – Apr	53.68 (50.75 to 56.60) *	1.68 (1.11 to 2.26)	1.12 (0.59 to 1.64)
Apr – Jul	55.29 (52.35 to 58.23) **	1.59 (1.08 to 2.11)	1.51 (0.93 to 2.08)
Jul – Sept	54.26 (50.62 to 57.90) **	0.92 (0.47 to 1.36)	1.11 (0.62 to 1.6)

* significant difference to Nov-Jan. ** significant difference to Nov-Jan and Jan-Apr.

Table 2:

Table 2: Time-loss (TL) and medical attention (MA) injuries collected in home (HG) and training groups (TG) from November 2018 until September 2019.

Variable	HG (n = 33)	TG (n = 33)
No. of all TL + MA injuries	63	76
TL + MA Injury Incidence (95% CI)	13 (10.1 to 16.6)	15.6 (12.1 to 16.9)
No. of TL injuries (% of all injuries)	50 (79.4)	54 (71)
TL Injury burden (95% CI)	184.6 (172.9 to 197)	166.2 (155.2 to 178.1)
No. MA injuries (% of all injuries)	13 (20.6)	22 (29)
Mean days with MA injury (95% CI)	4.6 (0.5 to 8.6)	5.00 (1.6 to 8.4)

FIGURES

Figure 1:

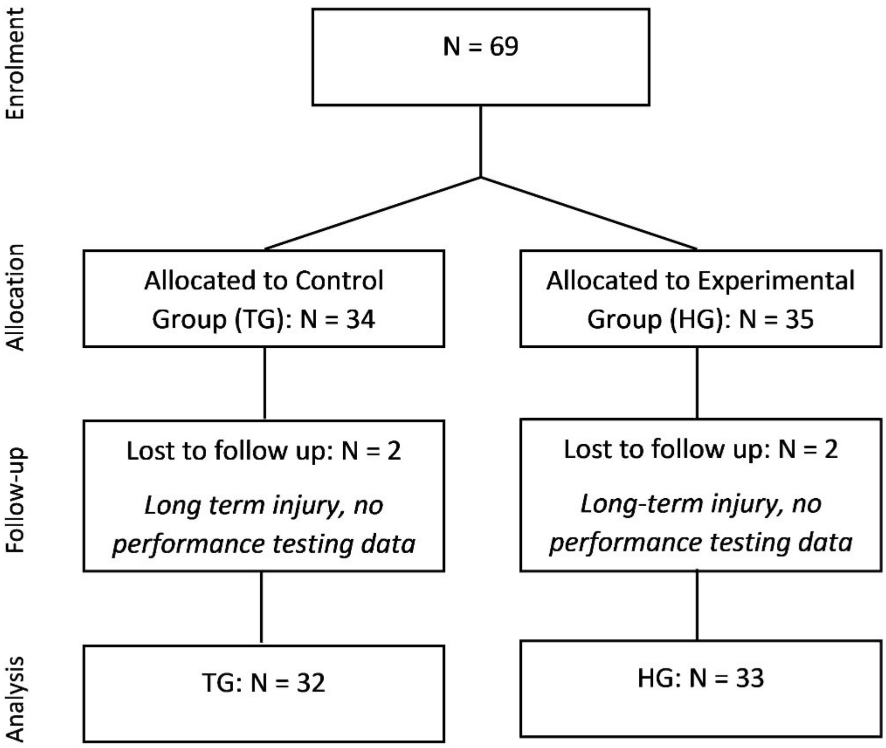


Figure 2:

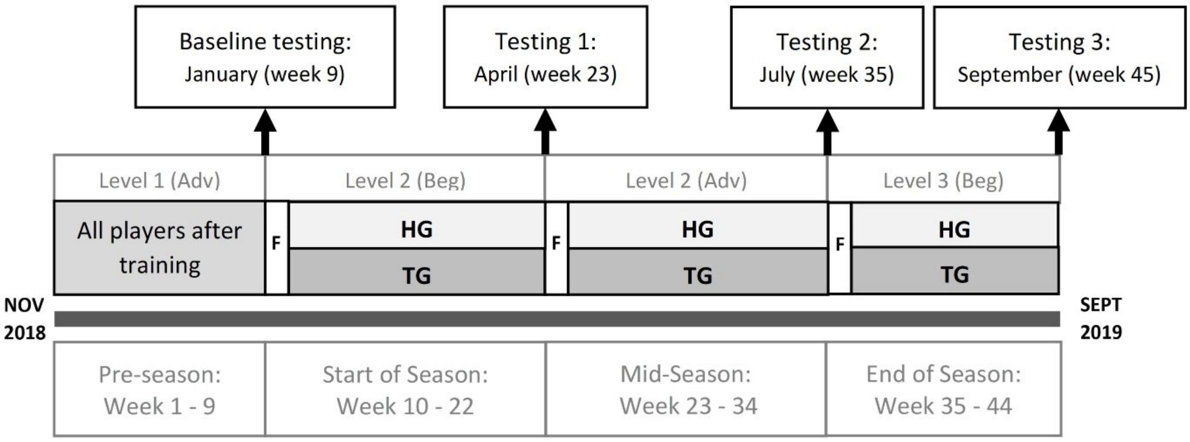

Baseline testing:
January (week 9)
Testing 1:
April (week 23)
Testing 2:
July (week 35)
Testing 3:
September (week 45)
Level 1 (Adv)
Level 2 (Beg)
Level 2 (Adv)
Level 3 (Beg)
All players after training
F
HG
TG
F
HG
TG
F
HG
TG
NOV 2018
SEPT 2019
Pre-season: Week 1 - 9
Start of Season: Week 10 - 22
Mid-Season: Week 23 - 34
End of Season: Week 35 - 44

Figure 3:

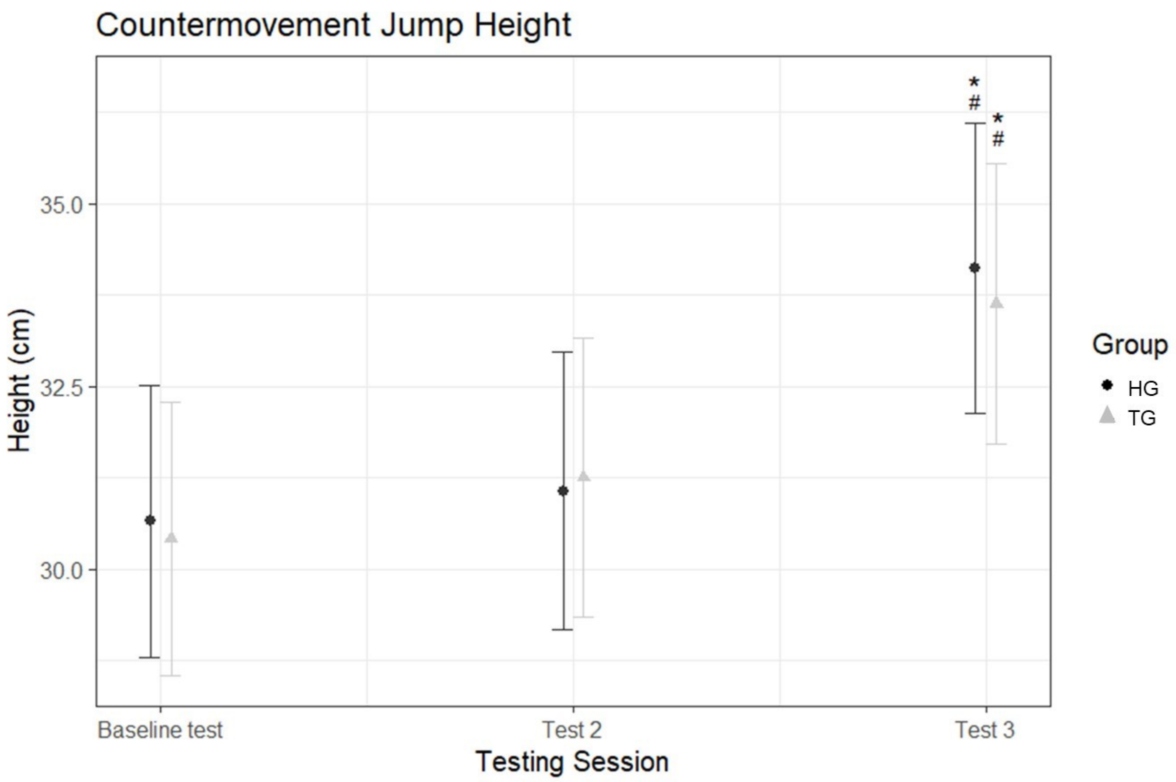
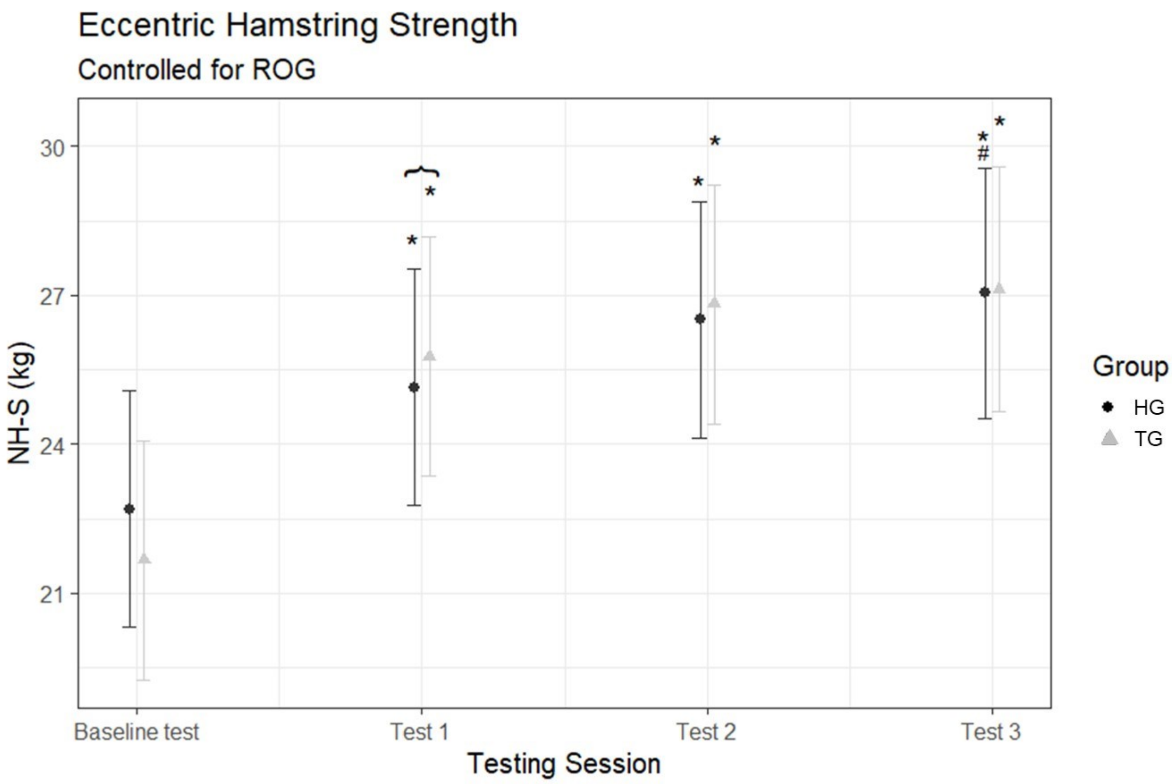

Countermovement Jump Height
Height (cm)
35.0
32.5
30.0
Baseline test
Test 2
Test 3
Testing Session
Group
HG
TG
*
#
*
#

Figure 4:



Eccentric Hamstring Strength
Controlled for ROG
30
27
24
21
NH-S (kg)
Baseline test
Test 1
Test 2
Test 3
Testing Session
Group
HG
TG

FIGURE CAPTIONS

Figure 1: Diagram of the flow of participants in the study according to the Consolidated Standards of Reporting Trials (CONSORT).

Figure 2: Timeline for the progression and delivery of 11+ exercises for the home group (HG) and training group (TG). 'Level' refers to the difficulty level of Part 2 of the 11+. Adv = advanced. Beg = Beginner. F = Familiarisation week.

Figure 3: Countermovement jump height recorded in home (HG, black lines and circles) and training (TG, grey lines and triangles) groups. * significant difference to Baseline test. # significant difference to Test 2.

Figure 4: Eccentric hamstring strength gains, controlled for rate of growth (ROG) in home (HG, black lines and circles) and training (TG, grey lines and triangles) groups. * significant difference to Baseline test. # significant difference to Test 1. { significant group × time interaction versus baseline.