BMJ Open Sport & Exercise Medicine

Performing Nordic hamstring strength testing with additional weight affects the maximal eccentric force measured: do not compare apples to oranges

Roar Amundsen ,[1] Merete Møller ,[1,2] Roald Bahr [1]

To cite: Amundsen R, Møller M, Bahr R. Performing Nordic hamstring strength testing with additional weight affects the maximal eccentric force measured: do not compare apples to oranges. *BMJ Open Sport & Exercise Medicine* 2023;**9**:e001699. doi:10.1136/bmjsem-2023-001699

Accepted 31 October 2023

[1]Oslo Sports Trauma Research Center, Institute of Sports Medicine, Norwegian School of Sports Sciences, Oslo, Norway
[2]Department of Sports Science and Clinical Biomechanics, University of Southern Denmark, Odense, Denmark

Correspondence to
Roar Amundsen; roara@nih.no

ABSTRACT

Background Nordic hamstring test devices are commonly used to measure maximal eccentric hamstring force. The ability to control the final phase of the exercise has been adopted as a criterion to add weight when testing, without substantial evidence. We investigated if adding weight affected the maximal force measured, and if there were differences between players who could and could not control the final phase.

Methods Female (n=84) and male (n=56) football players performed a Nordic hamstring strength test with 0, 5 and 10 kg. We used visual inspection to assess the ability to control the final phase (approximately last 20°), as per previously published studies.

Results Maximal force was higher when tested with 5 kg (females: +8 N (2%), p<0.001; males: +18 N (4%), p<0.001) and 10 kg (females: +17 N (5%), p<0.001; males: +27 N (6%), p<0.001) compared with 0 kg. This was the case for both groups, those who could control the final phase (5 kg: +16 N (4%), p<0.001; 10 kg: +28 N (7%), p<0.001) and those who could not (5 kg: +9 N (3%), p<0.001; 10 kg: +15 N (4%), p<0.001).

Conclusion Both players who could and could not control the final phase of the Nordic hamstring test demonstrated higher maximal force when adding weight to testing. Therefore, this should not be used to decide if players should perform testing with or without weight. Either all participants or none should be tested with weight, and the same approach should be used both for pre-testing and post-testing.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Nordic hamstring strength testing is a common and reliable method to measure maximal eccentric hamstring strength. However, several studies have added weight to Nordic hamstring testing if participants are able to control the forward falling movement during the final phase of the test, without substantial evidence.

WHAT THIS STUDY ADDS

⇒ This study showed that participants, regardless of their ability to control the final phase of the test, displayed higher maximal eccentric hamstring force when performing Nordic hamstring strength testing with weight compared with testing without weight.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ To avoid potentially overestimating the effect of a training intervention or causing biased result, future research should not use the ability to control the final phase of the Nordic hamstring test to decide if participants should be tested with added weight or not.

INTRODUCTION

Hamstring injuries represent the most common injury in many sports involving high-speed running.[1–4] Most are thought to occur during the late swing phase when the hamstrings muscles must produce high eccentric force to decelerate the extending knee and flexing hip,[5] therefore low eccentric hamstring strength has been considered a risk factor. Data from prospective cohort studies examining the association between hamstring strength and hamstring injury risk are equivocal,[6–9] but systematic eccentric strength training reduces the risk of hamstring injuries.[10–13] Testing maximal eccentric hamstring strength has therefore become common practice both in research and in the real-world setting in these sports.

The eccentric strengthening exercise most used in research aiming to prevent hamstring injuries is the Nordic hamstring exercise.[10 12 13] Consequently, a test device that measures the eccentric hamstring force during the Nordic hamstring exercise was developed[14] and is now commonly used in both research[15] and by elite teams in various sports. During the test, the player's ankles are secured by braces attached to load cells. These measure the maximal eccentric hamstring force when the athlete leans forward and resists falling forward for as long as possible (ie, performing the Nordic hamstring exercise). The Nordic hamstring exercise is intended to be supramaximal, and a prerequisite for Nordic hamstring test devices is that the subject reaches a 'critical point' where the external load from gravity acting on the upper body exceeds their maximal eccentric hamstring strength.[14] However, some athletes are able to control the forward falling motion throughout the full range of motion of the exercise. These players will never reach the 'critical point' and the test will therefore not be able to measure their maximal eccentric hamstring strength as intended.

Some studies have addressed this problem. To ensure that supramaximal intensity is achieved, study participants who were able to control the final phase of the forward falling movement before full extension have performed training while holding weight plates, increasing the weight over the intervention period.[16–22] Several of these studies have used the same criterion when testing maximal eccentric hamstring force with Nordic hamstring test devices.[17–21] As maximal eccentric hamstring force measured during Nordic hamstring strength testing correlates with body mass,[23] it is possible that performing the test with added weight could affect the outcome, irrespective of changes in eccentric hamstring strength. This would be critical, especially if using different weights for pre-tests and post-tests when evaluating the effect of a training intervention or comparing groups that have performed the testing with different weights. Currently, no studies have examined how performing Nordic hamstring strength testing with added weight affects the maximal force measured.

Therefore, we aimed to investigate how adding extra weight when performing Nordic hamstring strength testing affected the maximal eccentric hamstring force recorded in male and female football players, and if there were any differences between players who were able to control the forward falling movement during the final phase of the range of motion and those who could not.

METHODS

Trial design and participants

We tested the maximal eccentric hamstring force of 140 football players (84 females: 171±6 cm, 65±6 kg, 22±4 years; 56 males: 183±6 cm, 78±9 kg, 24±4 years). The female players were from six different Norwegian premier league teams and performed the testing as part of annual pre-season testing at the Norwegian Football Association Sport Medicine Clinic before the 2021 season. The male players played for three first division teams (professional, second tier) and were tested at their team facility prior to the 2022 season. All participants were above 16 years old, part of the team's first team squad, free of injury and gave their individual consent to participate.

Strength testing

Eccentric hamstring strength was tested in a Nordic hamstring test device (NordBord V.1.0, Vald Performance, Albion, Australia). All players were using the Nordic hamstring exercise as part of their weekly training routine, eliminating the need for familiarisation with the test.[14] During the test, players knelt on the board and had their ankles secured by ankle hooks attached to uniaxial load cells. We instructed them to cross their arms in front of their chest, move slowly forward without bending their hip and use their hamstring muscles to maximally resist the forward falling motion for as long as possible. Players performed three submaximal warm-up repetitions, before performing three test sets with maximal effort: first three repetitions with no added weight, then one repetition with a 5 kg weight vest and finally one repetition with a 10 kg weight vest. The three test sets with maximal effort were separated by 1 min breaks.[24] For the set performed without added weight we assessed, by visual inspection, if the player was able to control the final phase of the forward falling movement (approximately 20°) or not, as per previously published studies.[17 18] In a separate test session after the 2022 season, 10 of the male players with control during the final phase of test without added weight were re-tested and performed the test not only with 0, 5 and 10 kg added weight, but also with 15 and 20 kg. For all test sets, we recorded the maximal force (N) produced in the right and left leg. The results are reported as the average of the maximal force recorded from the right and left leg in absolute terms (N) and relative to body weight (N/kg).

Statistical analysis

All statistical analyses were performed using SPSS (IBM SPSS Statistics V.28.0, Armonk, New York, USA). Normality was tested with Kolmogorov-Smirnov test. We calculated the Pearson correlation coefficient between body mass and the maximal force measured during the test without added weight. Repeated measures analysis of variances was used to analyse differences in maximal eccentric hamstring force between tests performed with different weights. This was done separately for female and male players, players with and without control during the final 20°, and for the male players who performed the extra test session with up to 20 kg of added weight. Mauchly's test was used to test the assumption of sphericity and, if violated, we used a Huynh-Feldt correction. We used independent sample t-tests to compare the change in maximal eccentric force caused by adding weight to the test between players who were able to control the forward falling motion during the final 20° and players who could not. The significance level was set at $p<0.05$ for all tests.

RESULTS

The absolute and relative eccentric force produced during the Nordic hamstring strength test with 0 kg, 5 kg and 10 kg added weight are presented in table 1. Body mass was correlated to the maximal force during the test without added weight for both female (r=0.48 (95% CI: 0.30 to 0.63), $p<0.001$) and male players (r=0.65 (95% CI: 0.46 to 0.78), $p<0.001$), and all players combined (r=0.76 (95% CI: 0.68 to 0.83), $p<0.001$). Performing the test with added weight had a significant effect on the maximal eccentric force measured for female ($p<0.001$, partial $\eta^2=0.35$) and male players ($p<0.001$, partial $\eta^2=0.55$).

Table 1 Absolute and relative eccentric force (mean±SD) during the Nordic hamstring test performed with 0, 5 and 10 kg added weight for female (n=84, 33 with control during the final 20°) and male players (n=56, 32 with control during the final 20°), as well as the mean percent change (with 95% CI) for the tests with 5 and 10 kg added weight

	Total			Control during final 20°			Not control during final 20°		
	0 kg	5 kg	10 kg	0 kg	5 kg	10 kg	0 kg	5 kg	10 kg
Females									
Absolute force (N)	335±45	343±53	352±54	369±28	380±37	390±38	313±41	319±48	337±48
Relative force (N/kg)	5.1±0.6	5.3±0.7	5.4±0.7	5.5±0.4	5.7±0.5	5.9±0.5	4.9±0.6	5.0±0.7	5.1±0.7
Change (%)		2% (1%–3%)	5% (4%–6%)		3% (1%–4%)	6% (4%–7%)		2% (0%–4%)	4% (3%–6%)
Males (n=56)									
Absolute force (N)	431±52	449±54	458±61	447±45	467±46	482±52	410±53	424±55	427±59
Relative force (N/kg)	5.5±0.5	5.8±0.6	5.9±0.7	5.8±0.3	6.1±0.4	6.3±0.4	5.2±0.5	5.4±0.6	5.4±0.6
Change (%)		4% (3%–5%)	6% (5%–7%)		5% (3%–6%)	8% (6%–9%)		4% (2%–5%)	4% (2%–6%)

Pairwise comparisons indicated that the maximal eccentric force was higher when the test was performed with 5 kg and 10 kg added weight than without added weight for both female (5 kg: +8 N (2%), 95% CI: 5 to 12 N, p<0.001; 10 kg: +17 N (5%), 95% CI: 13 to 21 N, p<0.001) and male players (5 kg: +18 N (4%), 95% CI: 13 to 22 N, p<0.001; 10 kg: +27 N (6%), 95% CI: 22 to 33 N, p<0.001). Adding weight when performing the test had a significant effect on the maximal eccentric force for players who could control the final phase of the movement (p<0.001, partial η^2=0.58) and for those who could not (p<0.001, partial η^2=0.30). Pairwise comparisons indicated that the players who could control the final phase displayed higher maximal eccentric force when tested with weight (5 kg: 16 N (4%), 95% CI: 12 to 20 N, p<0.001; 10 kg: 28 N (7%), 95% CI: 23 to 32 N, p<0.001, n=65), as did players who could not (5 kg: 9 N (3%), 95% CI: 5 to 13 N, p<0.001; 10 kg: 15 N (4%), 95% CI: 11 to 20 N, p<0.001, n=75).

Thirty-three female (39%) and 32 male players (57%) were able to control the movement during the final phase of the test without added weight. For female players, the increase in eccentric force when the test was performed with added weight did not differ between those who could and could not control the final phase of the test (5 kg, mean difference: 5 N, 95% CI: −3 to 12 N, p=0.22; 10 kg: 7 N, −1 to 15 N, p=0.10) (figure 1). Male players with control increased the eccentric force more than those without control when the test was performed with 10 kg (17 N, 7 to 27 N, p=0.004), but not with 5 kg (6 N, −2 to 15 N, p=0.16) (figure 1).

Of the 10 players who were asked to also test with 15 and 20 kg added weight, four completed the test with 15 kg before declining to add more weight, while six also tested with 20 kg. Figure 2 illustrates the change in force measured when these players performed the test with added weights compared with without added weight. For the six players completing all five test sets, the maximal eccentric force was significantly higher when tested with 15 kg added weight compared with 10 kg (15 N, 95% CI: 1 to 30 N, p=0.04), while there was no difference between the tests with 15 and 20 kg (−1 N, 95% CI: −22 to 23 N, p=0.95).

DISCUSSION

The main finding of this study was that performing the Nordic hamstring strength testing with additional weight increased the maximal eccentric force measured as compared with testing without additional weight. This was the case for both female and male players, for players who could control the final phase of the test and players who could not.

A fundamental principle for all strength training is that load needs to be progressively increased. In the Nordic hamstring exercise, load is increased as the athlete can withstand the forward fall longer,[25] but when subjects are able to control the full range of motion, additional load is needed. In the original study on the Nordic Hamstring Exercise, Mjølsnes *et al*[25] proposed that load could be increased by adding speed to the starting phase of the motion.[25] Later studies have added weight to the exercise for the same purpose, using the ability to control the final phase of the exercise as a criterion to decide if testing with added weight was needed or not.[16–22] Our results demonstrate that the maximal eccentric hamstring force measured in the Nordic hamstring strength test was significantly higher when players performed the test with added weight, regardless of their ability to control the final phase (figure 1 and table 1). We therefore suspect that using this criterion to decide which participants are tested with weight may have introduced bias to the results of several training intervention studies. If players are tested without weight in the pre-tests and with weight in the post-tests, the effect of the training intervention may be overestimated. Furthermore, if studies aim to compare groups using different training volumes or exercises,[17–19] the between-group analyses may be affected if weight use differs between groups. As an example, Behan *et al*[19] compared four groups using different training volumes of the Nordic hamstring exercise, and reported that 80% of participants performing training and post-testing with added weight (range: 5–20 kg) were in the

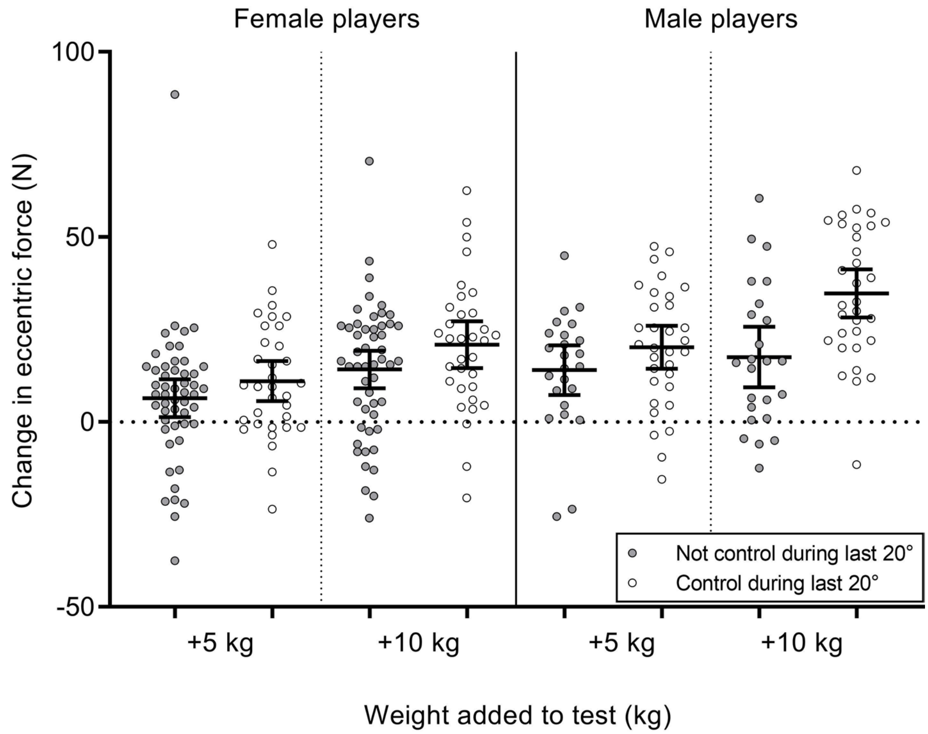

Figure 1 Difference in maximal eccentric force measured when the Nordic hamstring test was performed with 5 kg and 10 kg added weight compared with without added weight for female (n=84, left) and male players (n=56, right). Results are presented as mean with 95% CIs. Circles represent individual results from players who could control the final 20° of the test without weight (white) and players who could not (grey).

two higher-volume training groups of their study. Therefore, it is possible that the addition of weight caused an overestimation of the training effect in the two higher volume groups, but not (or to a lesser degree) in the lower volume groups.

Performing the Nordic hamstring testing without added weight, however, may also be problematic. If players are able to stop the movement during the final

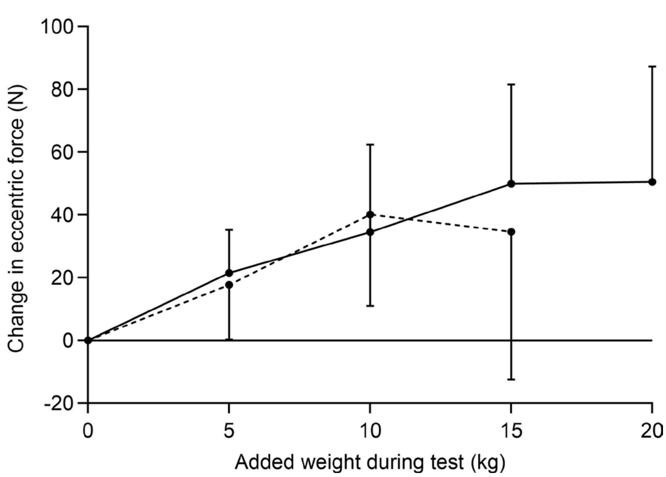

Figure 2 Change in maximal eccentric force measured when the test was performed with 5 kg, 10 kg, 15 kg and 20 kg added weight compared with without added weight (0 kg). Presented as mean±95% CIs for players that performed the test up to 15 kg added weight (dashed lines, n=4) and 20 kg added weight (solid lines, n=6).

phase of the test, this does not necessarily require their maximal force. No matter how much stronger these players become during a training intervention, the force required to stop the movement during the final phase of the test is likely to be the same. Testing these players without weight could therefore mask any changes in maximal strength. In a study where female football players performed an 8-week training intervention, we tested all players in the NordBord with 0, 5 and 10 kg added weight during both pre-testing and post-testing and we only compared tests where the same weight was used.[26] This approach prevents differences in added weight impacting the results, but also has some limitations. The appropriate weight for post-testing must be estimated in advance, and which weight is best suited to elicit maximal force could differ before and after a training intervention. In contrast to the current study, we found no differences between the maximal force on the tests performed with 0, 5 or 10 kg in the pre-tests.[26] The subjects in this study were playing on a lower level and we suspect that less experience with the Nordic hamstring exercise is a likely reason for the contrasting results, as the maximal force was higher when adding weight in the post-tests.[26]

A different approach, used by Duhig *et al*,[22] is to gradually increase the added weight until the player reaches a plateau in force. Figure 2 shows that the maximal eccentric hamstring force reached a plateau when players performed additional sets beyond 10 kg. How much weight is needed before the maximal force plateaus is likely highly individual and depends on the player's maximal eccentric hamstring strength but also other factors, such as body proportions, body mass, where the critical point occurs and the force–length relationship of the muscles. By using this approach, all players, regardless of their ability to control the final phase of the test, are tested with weight and can reach their maximal eccentric hamstring strength. We therefore consider this the best of the alternatives mentioned, although one should be aware that athletes may be reluctant to perform the Nordic hamstring test with much added weight. Few players in our study agreed to be tested beyond 10 kg. Of the 10 players who accepted, four players declined adding weight beyond 15 kg and the remaining six did not want to go beyond 20 kg, despite not all of them reaching a plateau in the force measured. Fear of muscle soreness is one of the main challenges in obtaining adherence to injury prevention programmes from football players,[27 28] and could also be a problem with Nordic hamstring strength testing with added weight.

Methodological considerations

One strength of the study is that we tested a high number of both female and male players. That the test was performed with gradually increasing weight rather than in a randomised order could, theoretically, have affected the force measured in the later sets both negatively and positively. Fatigue may have negatively affected the maximal force the players could produce in the latter sets. We consider this unlikely, as it has been shown that 1 min break between sets was sufficient to maintain the force-production qualities when performing the Nordic hamstring exercise.[24] On the other hand, players could have experienced a learning effect throughout the test and therefore performed better in the later sets. We also consider this unlikely as all players used the Nordic hamstring exercise as part of their weekly training routine and therefore were familiar with the exercise. Most players had also performed the Nordic hamstring strength test as part of annual pre-season testing in previous seasons. That players were experienced with the exercise is substantiated by the high maximal eccentric force they displayed; the female players (mean: 335 N) were slightly stronger than what has been reported from elite female athletes from different football codes (mean: 250–275 N),[29] and the male players' results (mean: 431 N) were comparable to results from men's Premier League and Champion's League football (400–425 N).[30] The increase we found in maximal force with added weight was similar to the measurement error of the test.[14] Therefore, care should be taken when interpreting the result from individual testing, keeping the measurement error in mind. Using visual inspection to determine which players are able to control the forward falling motion during the final 20° motion is likely tester dependent. The intra-rater and inter-rater reliability of this categorisation has not been tested and may be low. It is, nonetheless, an approach that has been adopted by several previous studies to decide which players should train and be tested with added weight.[16–22] The analysis of players performing the test with up to 20 kg added weight should be interpreted with care because of low statistical power. Also, the number of multiple comparisons may have increased the risk of making a type I error.

Clinical and research implications

Caution is needed when comparing Nordic hamstring strength tests that incorporate different weights during pre-testing versus post-testing. In the future, the ability to control the final phase of the forward falling motion should not be used as a criterion to decide which players should be tested with added weight; either all players should be tested with weight or none. If Nordic hamstring strength testing is performed with added weight, we recommend gradually increasing added weight until the force plateaus for all players on all tests. When studies conduct Nordic hamstring strength testing with added weight, the testing protocol used should be described in detail.

Twitter Roar Amundsen @roaramunds, Merete Møller @Merete_Moller and Roald Bahr @RoaldBahr

Acknowledgements We thank the participating players and teams, and acknowledge Morten Wang Fagerland and Lena Bache-Mathiesen for contributing with statistical advices. The Oslo Sports Trauma Research Center has been established at the Norwegian School of Sport Sciences through generous grants from the Royal Norwegian Ministry of Culture, the South-Eastern Norway Regional Health Authority, the International Olympic Committee, the Norwegian Olympic Committee & Confederation of Sport, and Norsk Tipping AS.

Contributors All authors were involved in the design of the study. RA conducted the testing, performed the statistical analyses and drafted the manuscript. All authors revised the manuscript and gave their final approval of the submitted version. RA act as guarantor for the study.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Ethics approval This study involves human participants and was approved by The Norwegian Centre for Research Data (#662612) and the Norwegian School of Sports Sciences Ethics Committee (#179-180321). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID iDs
Roar Amundsen http://orcid.org/0000-0003-2664-7753
Merete Møller http://orcid.org/0000-0001-7514-0399
Roald Bahr http://orcid.org/0000-0001-5725-4237

REFERENCES

1 Ekstrand J, Hägglund M, Kristenson K, *et al*. Fewer ligament injuries but no preventive effect on muscle injuries and severe injuries: an 11-year follow-up of the UEFA champions league injury study. *Br J Sports Med* 2013;47:732–7.
2 Hägglund M, Waldén M, Ekstrand J. Injuries among male and female elite football players. *Scand J Med Sci Sports* 2009;19:819–27.
3 Orchard J, Seward H. Epidemiology of injuries in the Australian football league, seasons 1997-2000. *Br J Sports Med* 2002;36:39–44.
4 Brooks JHM, Fuller CW, Kemp SPT, *et al*. Epidemiology of injuries in English professional Rugby Union: part 2 training injuries. *Br J Sports Med* 2005;39:767–75.
5 Danielsson A, Horvath A, Senorski C, *et al*. The mechanism of hamstring injuries - a systematic review. *BMC Musculoskelet Disord* 2020;21:641.
6 Green B, Bourne MN, Pizzari T. Isokinetic strength assessment offers limited predictive validity for detecting risk of future hamstring strain in sport: a systematic review and meta-analysis. *Br J Sports Med* 2018;52:329–36.
7 Opar DA, Williams MD, Timmins RG, *et al*. Eccentric hamstring strength and hamstring injury risk in Australian footballers. *Med Sci Sports Exerc* 2015;47:857–65.
8 van Dyk N, Bahr R, Burnett AF, *et al*. A comprehensive strength testing protocol offers no clinical value in predicting risk of hamstring injury: a prospective cohort study of 413 professional football players. *Br J Sports Med* 2017;51:1695–702.
9 van Dyk N, Bahr R, Whiteley R, *et al*. Hamstring and quadriceps Isokinetic strength deficits are weak risk factors for hamstring strain injuries: a 4-year cohort study. *Am J Sports Med* 2016;44:1789–95.
10 Arnason A, Andersen TE, Holme I, *et al*. Prevention of hamstring strains in elite soccer: an intervention study. *Scand J Med Sci Sports* 2008;18:40–8.
11 Askling C, Karlsson J, Thorstensson A. Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. *Scand J Med Sci Sports* 2003;13:244–50.
12 Petersen J, Thorborg K, Nielsen MB, *et al*. Preventive effect of eccentric training on acute hamstring injuries in men's soccer: a cluster-randomized controlled trial. *Am J Sports Med* 2011;39:2296–303.
13 van der Horst N, Smits D-W, Petersen J, *et al*. The preventive effect of the Nordic hamstring exercise on hamstring injuries in amateur soccer players: a randomized controlled trial. *Am J Sports Med* 2015;43:1316–23.
14 Opar DA, Piatkowski T, Williams MD, *et al*. A novel device using the Nordic hamstring exercise to assess eccentric knee flexor strength: a reliability and retrospective injury study. *J Orthop Sports Phys Ther* 2013;43:636–40.
15 Claudino JG, Cardoso Filho CA, Bittencourt NFN, *et al*. Eccentric strength assessment of hamstring muscles with new technologies: a systematic review of current methods and clinical implications. *Sports Med Open* 2021;7:10.
16 Bourne MN, Duhig SJ, Timmins RG, *et al*. Impact of the Nordic hamstring and hip extension exercises on hamstring architecture and morphology: implications for injury prevention. *Br J Sports Med* 2017;51:469–77.
17 Presland JD, Timmins RG, Bourne MN, *et al*. The effect of Nordic hamstring exercise training volume on biceps femoris long head architectural adaptation. *Scand J Med Sci Sports* 2018;28:1775–83.
18 Pollard CW, Opar DA, Williams MD, *et al*. Razor hamstring curl and Nordic hamstring exercise architectural adaptations: impact of exercise selection and intensity. *Scand J Med Sci Sports* 2019;29:706–15.
19 Behan FP, Vermeulen R, Whiteley R, *et al*. The dose-response of the Nordic hamstring exercise on biceps femoris architecture and eccentric knee flexor strength: a randomized Interventional trial. *Int J Sports Physiol Perform* 2022;17:646–54.
20 Timmins RG, Filopoulos D, Nguyen V, *et al*. Sprinting, strength, and architectural adaptations following hamstring training in Australian footballers. *Scand J Med Sci Sports* 2021;31:1276–89.
21 Cadu JP, Goreau V, Lacourpaille L. A very low volume of Nordic hamstring exercise increases maximal eccentric strength and reduces hamstring injury rate in professional soccer players. *J Sport Rehabil* 2022;31:1061–6.
22 Duhig SJ, Bourne MN, Buhmann RL, *et al*. Effect of concentric and eccentric hamstring training on Sprint recovery, strength and muscle architecture in inexperienced athletes. *J Sci Med Sport* 2019;22:769–74.
23 Buchheit M, Cholley Y, Nagel M, *et al*. The effect of body mass on eccentric knee-flexor strength assessed with an Instrumented nordic hamstring device (Nordbord) in football players. *Int J Sports Physiol Perform* 2016;11:721–6.
24 Drury B, Peacock D, Moran J, *et al*. Different interset rest intervals during the Nordic hamstrings exercise in young male athletes. *J Athl Train* 2021;56:952–9.
25 Mjølsnes R, Arnason A, Østhagen T, *et al*. A 10-week randomized trial comparing eccentric vs. concentric hamstring strength training in well-trained soccer players. *Scand J Med Sci Sports* 2004;14:311–7.
26 Amundsen R, Heimland JS, Thorarinsdottir S, *et al*. Effects of high and low training volume with the Nordic hamstring exercise on hamstring strength, jump height, and Sprint performance in female football players: a randomised trial. *Translational Sports Medicine* 2022;2022:1–9.
27 McCall A, Dupont G, Ekstrand J. Injury prevention strategies, coach compliance and player adherence of 33 of the UEFA elite club injury study teams: a survey of teams' head medical officers. *Br J Sports Med* 2016;50:725–30.
28 Chesterton P, Draper G, Portas M, *et al*. The uptake of Nordic hamstring exercise program for injury prevention in major league soccer and its barriers to implementation in practice. *J Sport Rehabil* 2022;31:576–81.
29 VALDPerformance. Female professional athletes: Nordic and hip ad/AB results. 2021. Available: https://valdperformance.com/female-professional-athletes-nordic-and-hip-ad-ab-results/
30 VALDPerformance. European football report season 2019-20: Nordic strength. 2020. Available: https://valdperformance.com/nordic-strength/