International Journal of Biology and Life Sciences
ISSN: 2957-9511 | Vol. 4, No. 3, 2023

Effect of Nordic Hamstring Exercises on the Balance of Knee Muscle Strength in Sprinters

Congshuai Wang *, Yingqi Wang

China College of Athletics, Beijing Sport University, Beijing 100084, China

*** Corresponding author:** Congshuai Wang (Email: wangcongshuai123@163.com)

Abstract: Objective: The purpose of this study was to investigate the effect of Nordic hamstring exercises on the balance of knee muscle strength in sprinters. Methods: In this paper, a total of 20 well-trained sprinters were selected as subjects to participate in this experiment, 10 of them were subjected to Nordic hamstring exercise intervention, and the other 10 were treated as control group without any intervention. At different time points before and after intervention, the isokinetic muscle strength and test system were used to analyze the changes of muscle strength of athletes after Nordic hamstring exercise intervention. Results: The H:Q functional ratio changed over time after the intervention: decreased by 0.072 from baseline 24 hours after the intervention, recovered by 0.039 from 24 hours at 48 hours, and recovered by 0.024 from 72 hours at 48 hours. In general, there was a significant decline at 24 hours, and then a gradual recovery at 48 and 72 hours, but a partial recovery was observed overall. Conclusions: After the Nordic hamstring exercise intervention, the H:Q functional ratio showed a significant decline at 24 hours, and then gradually recovered at 48 and 72 hours, but overall partial recovery was observed. It is suggested that the injury risk of sprinters will increase in the short term after intervention, and the injury risk can be avoided by at least 48 hours of recovery.

Keywords: Nordic Hamstrings; Sprinting; Balance of Muscle Strength; Sprint Performance.

1. Introduction

In the epidemiological research on injuries of track and field athletes abroad, a scholar (Alonso J M,2010) conducted a comprehensive investigation on the frequency and characteristics of sports injuries and diseases during the 2009 Berlin Track and Field World Championships. According to the investigation, a total of 236 injuries were reported. Including 262 injury sites and 269 different injury types, 135.4 injuries occurred per 1,000 active athletes. Among them, 80% of the injuries were from the lower extremity, the thigh strain was the most reported (13.8%), and the injury occurred during the competition, the injury rate was as high as 85.9%. After in-depth investigation and analysis, it was found that overuse (44.1%) was the most important cause of athlete injury. Therefore, it can be proved that it is necessary to increase systematic injury monitoring of sprinters in training and set up corresponding rehabilitation training means to prevent injury and reduce the incidence of injury.

Centrifugal exercise training is beneficial to peripheral and central nervous activity. Studies have shown that centrifugal exercise significantly improves the electro my activity of the quadriceps muscle and increases the recruitment/divergence rate of alpha motor neurons (Doguet,2017). The new data suggest that centrifugal exercise not only improves cortical excitability compared to centripetal exercise, but also targets specific motor control pathways in the brain to attenuate neuromuscular regulatory deficits caused by injury. Eeg showed higher amplitude and area of cortical activation in centrifugal movement compared to centripetal movement. Centrifugal contractions may be able to reverse this altered subcortical state, providing a pattern of neural activation similar to that seen in healthy controls, providing a better way to intervene in treatment. During centrifugal contraction, the spinal cord mechanism is inhibited, allowing the muscles to lengthen without reflexive contraction (Frazer,2015).

In recent years, foreign scholars have conducted empirical studies on the impact of Nordic hamstring training on sprint performance. (Ishi L,2018) A randomized controlled experiment was used to verify the effect of 10-week Nordic hamstring exercise (NHE) program on sprint performance of football players. The study found that after ten weeks of supervised evidence-based injury prevention centrifugal strength training of the hamstring muscles using NHE, the repetitive sprint performance of male soccer players did not significantly improve (p=0.056), but there was a possible trend toward improvement. In addition, the 10-meter sprint performance may have a moderate degree of improvement, and the peak strength and strength capacity of the centrifugal hamstring muscle show a large improvement. A randomised controlled trial of 14 male athletes (Siddle J,2018) examined changes in centrifugal hamstring strength, 10-metre sprint speed and change of direction (COD) performance after a Nordic hamstring training (NHC) intervention and after a 3-week suspension period. The study found that immediately after the intervention, there were significant differences between the Nordic hamstring training group in hamstring strength and sprint performance; Sprint performance improved after the suspension period, but no significant change in hamstring centrifugal strength was observed.

It can be seen from the current data that lower limb muscle injury is the most common in track and field sprint sports, and there is a high risk of injury and injury recurrence rate. Most of the reasons are the overuse of sprinters during running. Therefore, it is urgent to conduct regular injury monitoring for sprinters and formulate methods and strategies to prevent injuries.

2. Research Design

2.1. Experimental Subjects

In this study, the short-term effects of Nordic hamstring exercises on knee flexion and extension muscle balance and sprint performance of sprinters were studied.

2.2. Experimental Methods

2.2.1. Experimental Method

(1) Experiment period: October 10, 2022 - November 10, 2022

(2) Experimental location: 104 isokinetic Strength Laboratory and test hall on the first floor of Sports Science Building, Beijing Sport University.

(3) Equipment required for the experiment: IsoMed2000 isokinetic muscle strength testing and training system (German D.&R.Ferstl Gmbrl).

(4) Experimental subjects: 20 special sprint athletes from School of Education and School of Athletics of Beijing Sport University were selected.

Inclusion criteria: male; Age 18-22 years old; The dominant side is the right side; More than 3 years of exercise; The average weekly training days in the past six months are 5 days; No knee pain within six months before the test, and no history of hamstring strain within the past year; Understand and be able to complete a given number of Nordic hamstring exercises; Confirm to participate in this experiment.

Exclusion criteria: history of musculoskeletal system trauma and surgical history of lower limb knee joint; A history of hamstring strain or varying degree of injury within the past year.

(5) Experimental grouping: After preliminary screening, random grouping was adopted, with 10 people in the experimental group and 10 people in the control group.

Table 1. Basic information of subjects

Groups	Age (years)	Height (m)	Weight (kg)	Years of training (years)
Experimental group (n=10)	20.6±1.4	1.80±0.4	66±3.5	5.1±2.3
Control group (n=10)	20.9±1.2	1.78±0.9	69±1.2	5.6±4.2

(6) Experimental process:

The experiment lasted for three weeks, the first two weeks were pre-experiment, and the third week was formal experiment. Before the start of the formal experiment, the recruited subjects were first evaluated by anthropometric indicators (including height, weight, etc.), training years, previous injury history and other basic information to grasp the basic information of all subjects, and then preliminary screening was conducted according to the inclusion/exclusion criteria. Secondly, according to the subjects' completion of the test actions, subjects with similar levels were selected, and then randomly divided into 10 people in the experimental group and 10 people in the control group.

During the first week, subjects are familiarized with the movement points of Nordic hamstring training to ensure that all subjects understand and are familiar with the movement patterns and ensure the technical quality and training intensity at the time of the formal experiment. During this period, all subjects were required to participate in two Nordic hamstring movement trainings, with 3 groups of 5 times in each training, and the metronome was used to control the movement speed during the training process, so that the body leaned forward at a constant and steady rate of decline, and the centrifugal muscle tension of the hamstring muscle was maintained until the body was completely prone on the mat.

The second week is an interval week. Students majoring in biomechanics will explain the isokinetic muscle strength test movements. All subjects will watch and be familiar with the movements during the whole process, so as to avoid the learning effect affecting the test results and the subsequent experiment. At the same time, the normal operation of the instrument and equipment are tested to avoid the problems of the instrument and equipment during the formal experiment, which will have an impact on the health of the subjects.

The third week was the formal experiment stage. After the warm-up activation of 10 athletes in the experimental group through standard procedures, the test results before intervention were collected, and the test results were taken as the baseline value. This was followed by a complete Nordic hamstring training program consisting of 4 sets of 10 Nordic hamstring workouts with 3 minute intervals between sets. After intervention, knee muscle strength and sprint performance at 24, 48 and 72 hours were collected for analysis.

(7) Experimental Intervention Plan:

The load was controlled in 4 groups with 10 repetitions per group. No intervention was performed in the control group. During the experiment period, athletes in both groups maintained the same training form and training load, and maintained normal training activities during the pre-experiment week, except for the experimental group receiving additional Nordic hamstring intervention.

(8) Experimental collection index selection:

The Nordic hamstring exercise was used to intervene athletes of different sports, and the knee isokinetic muscle strength (peak moment of quadriceps contraction, peak moment of hamstring centrifugal contraction, H:Q function ratio) was tested after 24, 48 and 72 hours, respectively.

2.2.2. Mathematical Statistics

In this study, SPSS26.0 (IBM,NY.USA) software and Office Excel2016 were used for data sorting and analysis. Continuous variables are expressed as mean ± standard deviation. Shapiro-Wilk method was used for normality test, parametric test (t test or ANOVA) was used for data subject to normal distribution, and non-parametric test was used for data not subject to normal distribution.

3. Research Results

3.1. Changes of H:Q Function Ratio of Knee Joint at Different Angular Velocity and Time Points

In this study, the two-factor repeated measurement ANOVA method was used to determine the impact of changes in different angular velocities over time on the H:Q functional ratio of subjects, and the data were statistically described in the form of mean ± standard deviation (see Table 4.7). Shapiro-Wilk test showed that the data in each group were normally distributed ($P > 0.05$). Through the analysis of the student-oriented residuals, it is judged whether the student-oriented residuals exceed the standard deviation of ±3 times. According to Mauchly's sphericity hypothesis test, the data met the requirements of Mauchly's sphericity test ($P > 0.05$).

Therefore, the variance covariance matrix of the dependent variable was equal for the interaction term angular velocity * time (P > 0.05).

Table 2. H: Q function ratio of knee joint at different time points at different angular velocities

	Baseline value	24h	48h	72h	F	P
60°/s	0.67±0.05	0.61±0.047	0.64±0.055	0.66±0.057	15.195	<0.05
120°/s	0.78±0.067	0.69±0.047	0.75± 0.059	0.77±0.069	41.419	>0.05
F	18.414	15.167	18.558	17.004		
P	<0.001	<0.05	<0.001	>0.05		

Note: F_{time}=41.565, P_{time}<0.001; $F_{angular\ velocity}$=19.400, $P_{angular\ velocity}$<0.001; $F_{angular\ velocity\ time}$=2.495, $P_{group\ *time}$ > 0.05.

The interaction of angular velocity and time had no statistical significance on the function ratio of H:Q, F angular velocity * time =2.495, P=0.080 > 0.05. Therefore, it is necessary to interpret the main effects of two intra-subject factors (angular velocity and time). If the main effect of the in-subject factor at the > 2 level is present, a subsequent pairwise comparison is required.

The main effect of angular velocity on H:Q function ratio was statistically significant (F=19.400, P=0.000 < 0.001). The H:Q functional ratio at 60°/s was 0.105 lower than that at 120°/s (95% confidence interval: -0.155 ~ -0.055), and the difference was statistically significant (P=0.000 < 0.001).

The time factor had a statistically significant effect on the functional ratio of H:Q (F=53.202, P=0.000 < 0.001). Because the time factor has 4 levels, it is pairwise comparison. The difference between the H:Q functional ratio at baseline and the H:Q functional ratio at 24 hours was statistically significant (P=0.000 < 0.001), and the difference was 0.072(95% confidence interval: 0.053 ~ 0.090). The difference between the H:Q ratio at 24 hours and the H:Q ratio at 48 hours was statistically significant (P=0.000 < 0.001), and the difference was -0.039 (95% confidence interval: -0.060 ~ -0.018). The difference between the H:Q functional ratio at 48 hours and the H:Q functional ratio at 72 hours was statistically significant (P=0.021 < 0.05), and the difference was -0.024(95% confidence interval: -0.045 to -0.003).

3.2. Changes of H:Q Function Ratio of Knee Joint in Different Groups at Different Time Points

Table 3. 60%s H:Q functional ratios of different groups at different time points

	Baseline value	24h	48h	72h	F	P
Experimental group (n=10)	0.67±0.05	0.61±0.047	0.64±0.055	0.66±0.057	29.235	<0.001
Control group (n=10)	0.68±0.052	0.67±0.051	0.67±0.055	0.68±0.035	1.024	>0.05
F	0.373	6.979	2.029	0.819		
P	>0.05	<0.05	>0.05	>0.05		

Note: F_{time}=10.121, P_{time}<0.001; F_{group} =2.222, P_{group}>0.05; Group $F_{group*time}$=4.435, P $_{Group*Time}$<0.05.

Table 4. 20%s H :Q functional ratio of different groups at each time point

	Baseline value	24h	48h	72h	F	P
Experimental group (n=10)	0.78±0.067	0.69±0.047	0.75±0.059	0.77±0.069	61.633	<0.001
Control group (n=10)	0.79±0.057	0.78±0.059	0.78±0.062	0.79±0.054	0.042	>0.05
F	0.047	14.657	1.961	0.189		
P	>0.05	<0.05	>0.05	>0.05		

Note: F_{time}=32.241, P_{time}<0.001; F_{group}=2.071, P_{group}>0.05; $F_{group*time}$ =29.434, $P_{group*time}$<0.001.

Two-factor repeated measurement analysis of variance was used to determine the influence of changes in different groups on the H:Q functional ratio of subjects over time. The data were statistically described in the form of mean ± standard deviation. ShaPiro-Wilk test showed that the data in each group were normally distributed (P > 0.05). Through the analysis of the student-oriented residuals, it is judged whether the student-oriented residuals exceed the standard deviation of ±3 times. According to Mauchly's spherical hypothesis test, the variance covariance matrix of the dependent variable is equal for the interaction term group * time (P > 0.05).

The interaction between group and time had a statistically significant effect on the functional ratio of H:Q at an angular velocity of 60°/s (Table 4.8). Group F * time =4.435, P=0.013 < 0.05; The effect on the functional ratio of H:Q at an angular velocity of 120°/s (Table 4.9) was statistically significant, with group F * time =29.434, P=0.000 < 0.001. Therefore, the simple effects of two in-subject factors (group and time) for the H:Q function ratio at two angular velocities of 60°/s and 120°/s were examined, respectively.

H:Q function ratio at an angular velocity of 60°/s: (1)At baseline, the difference in H:Q function ratio between the control group (0.68±0.052) and the experimental group (0.67±0.05) was not statistically significant (F=0.373, P=0.549). (2) At 24h, the difference of H:Q function ratio between the control group (0.67±0.051) and the experimental group (0.61±0.047) was statistically significant, and the difference was -0.058(95% confidence interval: 0.012 ~ 0.104), F=6.979, P=0.017. (3) At 48h, the difference of H:Q function ratio between the control group (0.67±0.055) and the experimental group (0.64±0.055) was not statistically significant (F=2.029, P=0.171). (4) At 72h, the difference of H:Q function ratio between the control group (145.6±6.19Nm) and the experimental group (141.7±10.5Nm) was not statistically significant (F=0.819, P=0.377).

In the control group, the dependent variable conforms to the spherical hypothesis for the intra subject factor - time. The simple effect of the time factor on the H:Q functional ratio was not statistically significant (F=1.204, P=0.408). In the experimental group, for the in-subject factor - time, the dependent variable conforms to the spherical hypothesis, and the simple effect of the time factor on the H:Q function ratio is statistically significant, F=29.235, P=0.000 < 0.001.

The difference between the H:Q functional ratio at baseline and the H:Q functional ratio at 24 hours was statistically significant (P=0.000), and the difference was 0.056(95% confidence interval: 0.033 ~ 0.079). The H:Q ratio at 24 hours was significantly different from the H:Q ratio at 48 hours (P=0.025), and the difference was -0.025(95% confidence interval: -0.048 ~ -0.002). There was no significant difference between the H:Q functional ratio at 48 hours and the H:Q functional ratio at 72 hours (P=0.447).

H:Q functional ratio at 120°/s: (1) At baseline, the difference in H:Q functional ratio between the control group (0.79±0.057) and the experimental group (0.78±0.067) was not statistically significant (F=0.047, P=0.831). (2) At 24h, the difference of H:Q function ratio between the control group (0.78±0.059) and the experimental group (0.69±0.047) was statistically significant, and the difference was 0.091(95% confidence interval: -0.041 ~ 0.141), F=14.657, P=0.001. (3) At 48h, the difference of H:Q function ratio between the control group (0.78±0.062) and the experimental group (0.75±0.059) was not statistically significant (F=1.961, P=0.178). (4) At 72h, the difference of H:Q function ratio between the control group (0.79±0.054) and the experimental group (0.77±0.069) was not statistically significant (F=0.189, P=0.669).

In the control group, the dependent variable conforms to the spherical hypothesis for the intra subject factor - time. The simple effect of time on H:Q function ratio was not statistically significant (F=0.042, P=0.988 > 0.05). In the experimental group, the dependent variable conforms to the spherical hypothesis for the insubject factor - time. The simple effect of time on the H:Q functional ratio was statistically significant (F=61.633, P=0.000 < 0.001). The difference between the H:Q functional ratio at baseline and the H:Q functional ratio at 24 hours was statistically significant (P=0.000), and the difference was 0.087(95% confidence interval: 0.068 ~ 0.106). The H:Q ratio at 24 hours was significantly different from the H:Q ratio at 48 hours (P=0.000), and the difference was -0.053(95% confidence interval: -0.081 ~ -0.025). The difference between the H:Q ratio at 48 hours and the H:Q ratio at 72 hours was not statistically significant (P=0.101).

4. Discuss

Knee flexor and extensor muscles are important power sources of running, and the balance of joint flexor and extensor muscles plays a crucial role in maintaining the dynamic stability of the knee joint (W J Zhang,2017). This study studied the effect of Nordic hamstring exercises on the knee flexion and extension muscle balance of sprinters. The study found that the H:Q functional ratio changed over time after the intervention: decreased by 0.072 from baseline 24 hours after the intervention, recovered by 0.039 from 24 hours at 48 hours, and recovered by 0.024 from 72 hours at 48 hours. In general, there was a significant decline at 24 hours, and then a gradual recovery at 48 and 72 hours, but a partial recovery was observed overall.

Overall, after the Nordic hamstring intervention, a clear downward trend in the ratio of H:Q function was seen after 24 hours. There are many reasons for this:

Since Nordic hamstring exercises are distal stationary centrifugal training methods, it is also necessary to consider the effect of centrifugal exercise training on muscle tissue structure, which can affect muscles in many ways. Studies have shown that the process of muscle soreness after stimulation of centrifugal exercise training is the process of myofibrillar and skeletal protein reconstruction, which is the performance of muscle initiative and adaptation. Muscle soreness will affect muscle strength to a certain extent, resulting in the phenomenon of muscle strength reduction of athletes after intervention (H P Zhang,2007). Other studies have shown that when athletes carry out sports they have never used or are unfamiliar with, especially centrifugal exercise, it is easy to cause skeletal muscle damage, mainly manifested as ultrastructural changes of skeletal muscle. And delayed muscle soreness syndrome such as decreased muscle strength, muscle soreness, swelling, and increased creatine kinase concentration in the blood (Brockett CL,2001). Therefore, this study is consistent with the conclusions of previous studies, and once again verified the phenomenon of muscle soreness and ultrastructural damage within 48 hours after centrifugal training. Therefore, muscle strength of the athletes decreased within 48 hours after the intervention, and the H:Q functional ratio calculated by "peak moment of centrifugal contraction of the hamstring/peak moment of centriardial contraction of the quadric muscle" also showed a decrease due to the decline of centrifugal muscle strength of the hamstring muscle, which indicated that the risk of hamstring injury of sprinter was further increased. At the same time, as the hamstring muscle is an important muscle group that generates horizontal force when sprinters accelerate and sprint (Hori M,2020), the maximum speed and maximum power of sprinters during 30 meters running also decrease.

5. Conclusion

After the Nordic hamstring exercise intervention, the H:Q function ratio showed a significant decline at 24 hours, and then gradually recovered at 48 and 72 hours, but an overall partial recovery was observed. It is suggested that the injury risk of sprinters will increase in the short term after intervention, and the injury risk can be avoided by at least 48 hours of recovery.

References

[1] Alonso J M, Tscholl P M , Engebretsen L ,et al. Occurrence of injuries and illnesses during the 2009 IAAF World Athletics Championships, British journal of sports medicine, Vol. 43 (2010) No.3, p.305-307.

[2] Doguet, Valentin Nosaka, Kazunori Guevel, Arnaud Thick broom, Gary Ishimura, Kazuhiro Ju beau, Marc. Muscle length effect on corticospinal excitability during maximal concentric, isometric and eccentric contractions of the knee extensors, Experimental Physiology, Vol. 102 (2017) No.11, p.650-661.

[3] Frazer, A,K, et al. Increased cross-education of muscle strength and reduced corticospinal inhibition following eccentric strength training, Neuroscience: An International Journal under the Editorial Direction of IBRO, Vol. 303(2015) No.6, p. 634-634.

[4] Ishi L , Hlmich P , Aagaard P , et al. Effects of the Nordic Hamstring exercise on sprint capacityin male football players:

a randomized controlled trial, Journal of Sports Sciences, Vol. 36(2018) No.14, p.1663.

[5] Siddle J, Greig M , Weaver K , et al. Acute adaptations and subsequent preservation of strength and speed measures following a Nordic hamstring curl intervention: a randomised controlled trial, Journal of Sports Sciences, Vol. 45(2018) No.7, p.1-10.

[6] W J Zhang, X M Ye, D W Zhang, et al. Effect of hamstring isokinetic centrifugation training on knee function after anterior cruciate ligament reconstruction, Chinese Journal of Sports Medicine, Vol. 36(2017) No.9, p. 805-809.

[7] H P Zhang, J J Liu, M H Dong. Research Progress of Delayed-Onset Muscle Soreness, Journal of Shenyang Physical Education Institute, Vol. 42(2007) No.3, p.52-55.

[8] Brockett CL, Morgan DL, Proske U. Human hamstring muscles adapt to eccentric exercise by changing optimum length. Med Sci Sports Exerc. Vol. 33(2001) No.5, p. 783-90.