

Short-term effects of sports taping on navicular height, navicular drop and peak plantar pressure in healthy elite athletes

A within-subject comparison

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Abstract

Medial tibial stress syndrome (MTSS) is one of the most common exercise-induced leg pain. The navicular drop (ND) was identified as a risk factor for MTSS. This study aimed to evaluate the short-term effects of sports taping applied to the supporting lower leg during sitting, standing, walking, and jogging to restrict the ND in healthy elite athletes.

Twenty-four healthy elite athletes without a history of exercise-induced pain or injuries in the lower limbs participated in this study (median age: 21.00 years; 1st–3rd quartiles; 19.25–22.00). The 4 taping conditions were used: rigid taping (RT), kinesiology taping (KT), placebo taping (PT), and non-taping (NT). The order of taping techniques was randomly assigned. Normalized navicular height (NH), ND, and normalized ND evaluated using 3-dimensional motion analysis, and normalized peak plantar pressure (PP) were compared in 4 taping conditions during sitting, standing, walking, and jogging.

During sitting, the normalized NH of RT is higher than that of NT, KT, and PT ($\chi^2 = 17.30$, $P = .001$), while during jogging, the normalized NH of RT is higher than that of NT and PT ($\chi^2 = 10.55$, $P = .014$). The normalized peak PP of NT is higher than that of PT ($\chi^2 = 8.871$, $P = .031$) in the lateral midfoot region.

This study showed the RT technique maintained NH during sitting and jogging, and the RT technique could be an effective preventive and treatment strategy for MTSS.

Abbreviations: KT = kinesiology taping, MTSS = medial tibial stress syndrome, ND = navicular drop, NH = navicular height, NT = non-taping, PP = plantar pressure, PT = placebo taping, RT = rigid taping.

Keywords: medial tibial stress syndrome, navicular drop, navicular height, peak plantar pressure, sports taping

1. Introduction

Exercise-induced leg pain, a regional pain syndrome associated with exercises that could occur between the knee and ankle, is a common condition among athletes and people involved in recreational sports.^[1,2] The causes of exercise-induced leg pain include a wide range of conditions that involve different tissues: bones, muscles, blood vessels, nerves, and tendons.^[1] Medial tibial stress syndrome (MTSS) is one of the most common exercise-induced leg pain.^[3] In a retrospective review of 150 athletes with exercise-induced leg pain, 13% had MTSS.^[4]

Moreover, the incidence rate of MTSS reported was 4% to 35% in athletics.^[1]

Running or impact loading of the lower limb creates stress within the tibia, resulting in MTSS that typically limits activity.^[5] However, the etiology of MTSS remains unknown.^[1] In previous studies, more than 100 risk factors associated with MTSS were proposed,^[5] while in 2 recent meta-analysis studies, 3 factors were identified as risk factors: navicular drop (ND), body mass index, and hip external rotation.^[6,7] However, careful attention to body mass index is necessary, as it is a poor indicator of body fat in certain populations,^[8] and the relationship between hip external rotation range of motion and MTSS is not well established.^[5] Although ND overlaps among individuals with and without MTSS,^[5] a person with ND >10mm is twice as likely to develop MTSS.^[6]

The prevention of MTSS is difficult because the causes remain unknown.^[9] Nevertheless, some authors suggested that MTSS preventive programs for individuals with increased ND may include pronation-control devices.^[9,10] Sports taping has long been used by elite athletes to provide mechanical support to the musculoskeletal system,^[11] and several authors reported that taping could control the ND.^[12,13] However, objective evidence supporting that sports taping restricts ND is extremely limited.^[9]

Therefore, this study aimed to evaluate the short-term effects of sports taping applied to the supporting lower leg in healthy elite athletes by assessing the navicular height (NH) and ND via 3-dimensional motion analysis, and also plantar pressure (PP) through platform in four taping conditions during static and dynamic activities.

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The authors report no conflicts of interest.

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Table 1**Participants' characteristics.**

	Gender		Age, y	Height, cm	Weight, kg	BMI, kg/m ²	Truncated foot length, mm
	Female	Male					
Total (n=24)	17 (70.8)	7 (29.2)	21.00 (19.25, 22.00)	181.00 (170.25, 184.75)	86.50 (75.50, 97.00)	27.13 (25.09, 29.57)	193.51 (178.52, 199.80)

Values expressed frequency (percentage) or median (1st quartile, 3rd quartile) depending on a characteristic of variables.

BMI = body mass index.

2. Methods

2.1. Ethical approval

This study was approved by the institution's ethics and research review committee at the Korea Institute of Sport Science. All participants provided a written informed consent.

2.2. Design

This study used a within-subject design for identifying the short-term effects of sports taping on NH, ND, and PP; no follow-up was conducted.

2.3. Participants

Thirty healthy elite university student athletes volunteered to participate in the study. Subjects were screened for eligibility based on their health status. Four had a history of exercise-induced pain or injuries in the lower limbs 6 months before the study and thus, were excluded. A detailed description of the test procedure was provided to the remaining 26 participants, who completed a self-report questionnaire regarding their demographic information. Two athletes who had a ≥ 10 -mm ND during weight bearing, which is indicative of excessive pronated foot,^[14] were further excluded. A total of 24 participants were included in the study. Table 1 summarizes the participants' characteristics.

2.4. Experimental procedure

The study was performed at the Department of Sport Science, Korea Institute of Sport Science, and Taereung National Training Centre. A 19-camera motion capture system (Oqus, Qualisys, Sweden) sampling at 250Hz was used to record navicular position data of passive reflective markers of each participant.^[15] All cameras were arranged and installed to smoothly measure the position in a 10-m walkway. Before navicular data collection, a global frame was created based on calibration trials via nonlinear transformation for 60seconds. The fourth-order Butterworth low-pass filter with a cut-off frequency of 15Hz was used to eliminate noises from skin movements or labeling errors; the data were processed using Qualisys Track Manager (Qualisys, Gothenburg, Sweden).^[16]

Participants completed the test while barefoot with their dominant leg in which they kick a ball. First, the height, body weight, and truncated foot length of each participant were assessed by a single investigator. Truncated foot length was defined as the perpendicular distance from the first metatarsophalangeal joint to the most posterior aspect of the heel.^[17] Thereafter, 10 reflective markers were placed on each participant's foot, as previously described^[18,19] (Fig. 1); the participants were seated with the subtalar joint in a neutral position,^[20] and then, they were instructed to sit, stand, walk, and jog, in order, as described below.

For the NH during sitting or nonweight bearing, all participants were instructed to sit on a chair with hip, knee, and talocrural joints flexed at 90° and to place their foot with the subtalar joint in a neutral position.^[21] For the NH and peak PP during standing or weight bearing, participants were asked to bear fully their body weight on their dominant leg over the platform. During walking and jogging, they were instructed to walk or jog on a treadmill at their own pace for 6 minutes, in accordance with each velocity.^[20] Thereafter, they walked or jogged at their own speed in a 10-m calibrated walkway and were instructed to have their heel touch the platform first. All participants had a 10-minute rest between tests to minimize any carry-over effects.

2.5. Measures

2.5.1. Navicular height and normalized navicular height. The NH during sitting or standing was the perpendicular distance between the marker on the navicular tuberosity and the imaginary line between the markers on the calcaneus and first metatarsal head.^[20,22] Five test trials were performed and the average was calculated for the analysis. During walking or jogging, the NH was identified at the time to the minimal NH from the floor.^[22] This NH measurement method was found highly reliable in a test/retest pilot study within a day (intraclass correlation coefficient = 0.94) and between days (intraclass correlation coefficient = 0.89). In normalizing the NH, the measured NH was divided by the participant's truncated foot length,^[23] and the results were used for data analysis in this study.

2.5.2. Navicular drop and normalized navicular drop. The ND during weight bearing was calculated as the NH of sitting minus that of standing. The ND during walking or jogging was calculated as the NH at heel strike minus that at the time to the minimal NH from the floor.^[22] In normalizing the ND, the calculated ND was divided by the participant's truncated foot length.^[23]

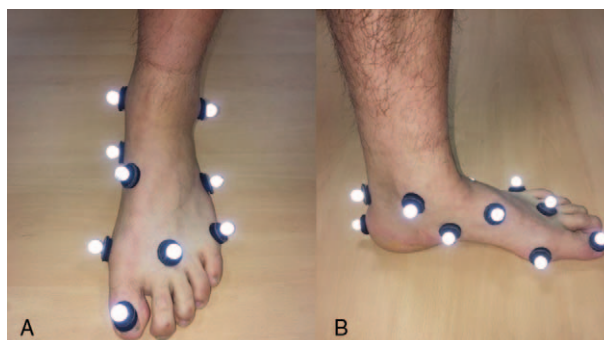


Figure 1. Reflective marker positions used to measure navicular height (NH) and calculate navicular drop (ND). (A) Frontal view and (B) medial view.

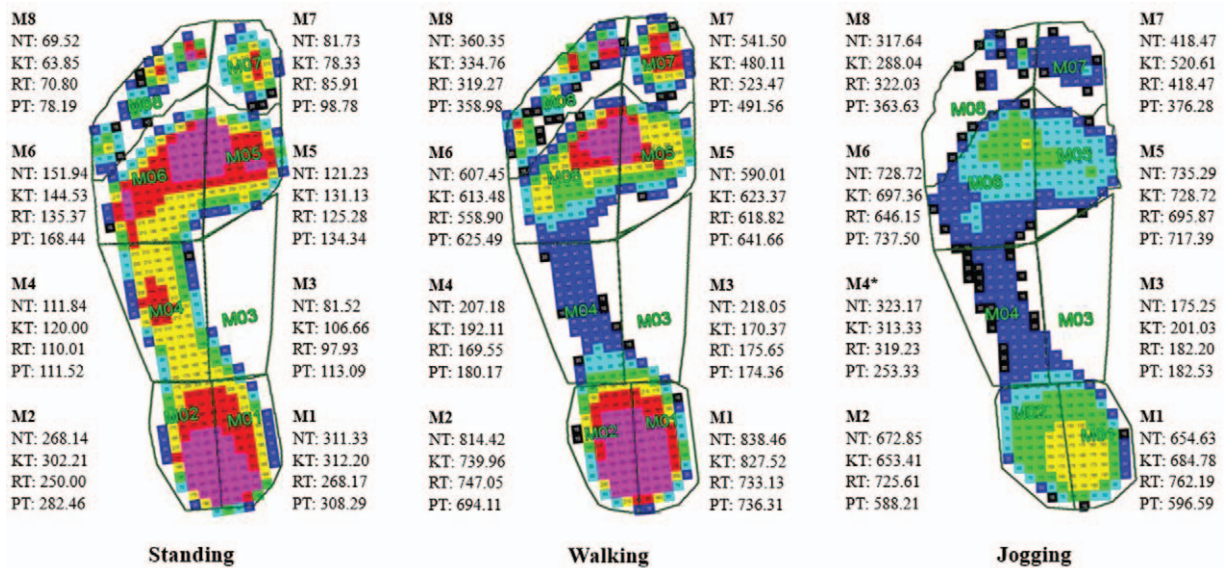


Figure 2. Normalized peak plantar pressures (PP) during standing, walking, and jogging (unit: %Body weight). * $P < .05$ by using Friedman test for identification of differences among taping conditions. M01: medial rearfoot, M02: lateral rearfoot, M03: medial midfoot, M04: lateral midfoot, M05: medial forefoot, M06: lateral forefoot, M07: big toe, M08: other toes, KT = kinesiology taping, NT = non-taping, PT = placebo taping, RT = rigid taping.

2.5.3. Normalized peak plantar pressure. The peak PP data were collected using emed-q100 platform (Novel Inc., GmbH, Germany), which is known as a reliable measurement tool of foot assessment during static and dynamic activities.^[24] It consisted of a 47.5cm × 32cm sensor matrix with a resolution of 4 sensors/cm² and the sampling frequency was fixed at 100Hz. This platform was mounted at the center of a 10-m runway at floor level.^[24,25] For data analysis, the foot was divided into 8 regions (Fig. 2).^[24,26,27] These regions were determined by drawing temporarily a rectangle fitting the medial/lateral sides and fore/rear sides of the footprint.^[28] To separate the rearfoot and the midfoot, straight lines were placed at 73% of the total foot length from the toes.^[28] The boundary between the midfoot and the forefoot was defined as 45% of the foot length from the toes, while that between the forefoot and the toes was defined by considering the pressure gradients around these maximum values.^[28] The peak PP, which provides an indirect representation of subtalar joint movement,^[29] was used during standing, walking, and jogging. This method for peak PP measurement was found to be highly reliable in a test/retest pilot study within a day (intraclass correlation coefficient = 0.94) and between days (intraclass correlation coefficient = 0.93). In normalizing the peak PP, the calculated peak PP was divided by the participant's body weight^[28]; the results were used for data analysis in this study.

2.6. Sports taping techniques

We used 4 taping conditions: rigid taping (RT), which is known to restrict translation generated in the unstable joint; kinesiology taping (KT), which corrects joint alignment^[11]; placebo taping (PT); and non-taping (NT). A specialized sports physiotherapist with >15 years of experience performed the sports tapings for all participants (Fig. 3). The order of taping techniques was randomly assigned, and before applying the tape to the foot and lower leg, the skin was cleaned with an alcohol swab.^[30]

RT was performed using a 35-cm rigid tape (Euro Tape; Muller, Prairie du Sac, WI), according to a modified technique

reported by Newell et al.^[26] Starting at the lateral malleolus of the ankle, the tape was attached laterally across the metatarsals and continued over the fifth metatarsal base (Fig. 3B), to the foot on the plantar surface, to the first metatarsal base, and under the navicular tuberosity (Fig. 3A). The tape passed over the aspect of the ankle and wrapped around the lower leg. To prevent skin irritation, a hypoallergenic undertape (Fixomull stretch; Beiersdorf Australia Ltd., Sydney, New South Wales, Australia) was naturally applied without any force in the same manner before applying the rigid tape.^[31]

KT, as reported by Aguilar and Merino-Marbán,^[32] was performed using a Kinesio tape (Kinesio USA Corporation, Ltd., Albuquerque, NM) (Fig. 3C). Two 25-cm strips were used: 1 strip was applied to the rearfoot with 75% stretch from the lateral malleolus to the middle third of the medial tibia, and the other was applied to the midfoot from the base of the fifth metatarsal

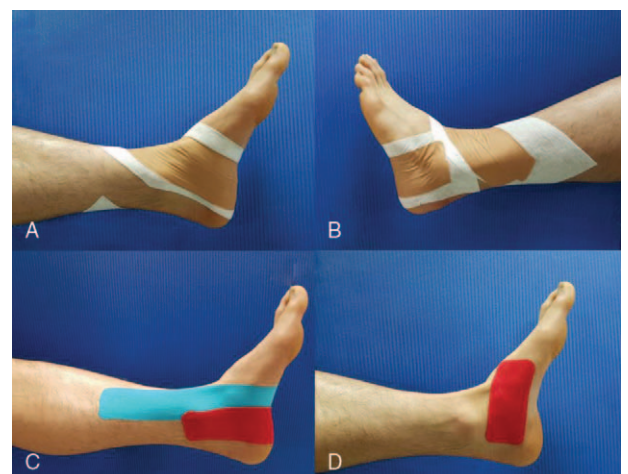


Figure 3. Taping techniques. Rigid taping: A, medial view and B, lateral view. Kinesiology taping: C, medial view. Placebo taping: D, medial view.

bone, across the talonavicular joint, to the internal aspect of the middle third tibia, also with 75% stretch. Participants in supine position were instructed to maintain the supinated rearfoot and the dorsiflexed ankle until completion of the taping.

To simulate the experimental taping techniques without the mechanical effect,^[32] PT was performed as reported by Thelen et al^[33] (Fig. 3D); however, no tension or any mechanical correction was applied. An 8-cm Kinesio tape placed horizontally on the medial aspect of the ankle without tension was used in PT.

A NT condition was also included, which served as a control condition for comparison with the other tapings.

2.7. Statistical analysis

All data were analyzed using SPSS version 21.0 for Windows (SPSS Inc., Chicago, IL). The Shapiro–Wilk test was employed to test for normality of distribution of variables; the null hypothesis for normality was rejected ($P < .05$). Hence, the Friedman test followed by Wilcoxon signed-ranks post-hoc test was used to compare each variable in the 4 taping conditions. Spearman correlation (ρ) was used to determine the correlation of NH or peak PP between the test and the retest pilot study. Statistical significance was identified at $P < .05$; all data were expressed as median and quartiles (1st and 3rd).

3. Results

3.1. Normalized navicular height

The normalized NH showed differences among the taping conditions during sitting ($\chi^2 = 17.30, P = .001$) and jogging ($\chi^2 = 10.55, P = .014$) (Fig. 4). During sitting, the normalized NH of RT (median, 1st–3rd quartiles: 2.10% truncated foot length, 1.86–2.15) was higher than that of NT (1.89% truncated foot length, 1.78–2.04; $Z = -2.914, P = .004$), KT (1.92% truncated foot length, 1.83–2.04; $Z = -2.714, P = .007$), and PT (1.81% truncated foot length, 1.68–2.05; $Z = -3.000, P = .003$). During jogging, the normalized NH of RT (1.83% truncated foot length, 1.64–2.00) was higher than that of NT (1.70% truncated foot length, 1.51–1.87; $Z = -2.057, P = .04$) and PT (1.63% truncated foot length, 1.50–1.73; $Z = -2.657, P = .008$).

3.2. Navicular drop and normalized navicular drop

The differences in both ND and normalized ND among the taping conditions were insignificant during weight bearing, walking, and jogging (Table 2).

3.3. Normalized peak plantar pressures

The normalized peak PP in a separated region showed that the differences among the taping conditions were insignificant during

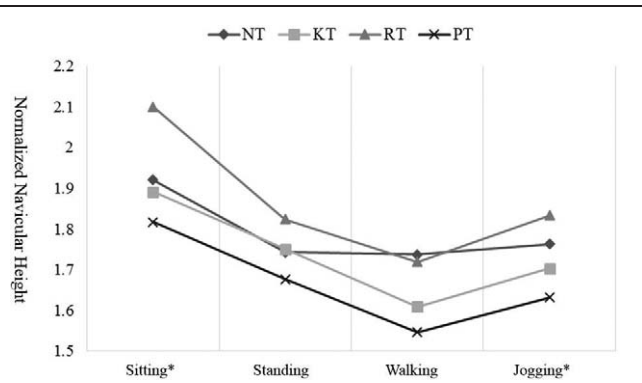


Figure 4. Normalized navicular height (NH) of 4 taping conditions during sitting, standing, walking, and jogging (unit: %Truncated foot length). * $P < .05$ by using a Friedman test for identification of differences among taping conditions. KT = kinesiology taping, NT = non-taping, PT = placebo taping, RT = rigid taping.

both weight bearing and walking (Fig. 2). However, in the lateral midfoot region, the differences in normalized peak PP among the taping conditions were significant during jogging ($\chi^2 = 8.871, P = .031$), that is, the normalized peak PP of NT (323.17% body weight, 266.80–364.13) was higher than that of PT (253.33% body weight, 225.00–358.69; $Z = -2.251, P = .024$).

4. Discussion

An excessive foot pronation has been associated with sports-related injuries of the lower extremities.^[34–36] For the management of symptoms related to excessive pronation at the subtalar joint, Low-Dye taping is widely used.^[37] Previous literature mentioned that Low-Dye taping could be useful to increase arch height and to reduce tibialis posterior activation during walking^[37–39]; however, skills and training for application are vital. A previous study reported that both Low-Dye taping and navicular-sling taping, which was used in this study, increased PP in the lateral midfoot region compared with the no-tape condition, and even navicular-sling taping led to a higher NH immediately after application.^[26] Therefore, the taping technique that is relatively easy to apply was used in this study.

Although taping techniques and measurement methods used in this study were different from those of other previous studies, the aim of this study was consistent with that of other studies, that is, to identify the effects of taping on ND and NH.^[26,40–42] Previous studies^[26,40,41] reported that taping to restrict ND helps in controlling excessive foot pronation initially after application. A previous study proposed that the differences in NH between

		NT	KT	RT	PT	χ^2 (P)
ND (unit: mm)	Weight-bearing	3.52 (1.29, 5.00)	3.43 (1.58, 5.37)	3.16 (1.82, 6.43)	2.62 (1.11, 4.25)	2.849 (.415)
	Walking	5.10 (2.42, 7.77)	4.92 (1.69, 5.90)	4.25 (2.78, 7.35)	4.41 (3.27, 7.84)	2.660 (.447)
	Jogging	4.45 (3.02, 5.68)	4.10 (2.71, 4.94)	3.38 (2.34, 5.09)	4.97 (3.73, 5.09)	7.800 (.050)
Normalized ND (unit: % Truncated foot length)	Weight-bearing	0.18 (0.07, 0.25)	0.17 (0.08, 0.26)	0.16 (0.10, 0.33)	0.13 (0.06, 0.21)	2.849 (.415)
	Walking	0.26 (0.13, 0.38)	0.27 (0.09, 0.28)	0.22 (0.14, 0.36)	0.25 (0.17, 0.41)	2.660 (.447)
	Jogging	0.23 (0.16, 0.28)	0.21 (0.14, 0.26)	0.18 (0.12, 0.29)	0.26 (0.19, 0.30)	7.800 (.050)

Values expressed median (1st quartile, 3rd quartile).

KT = kinesiology taping, ND = navicular drop, NT = non-taping, PT = placebo-taping, RT = rigid-taping.

before and after exercise or physical activities were insignificant regardless of the application of taping, which was attributed to diminished adherence to the skin, loss of tensile quality of the tape, or skin movement.^[26] In this study, the result showed that the NH of RT was higher than that of KT during sitting, which could be related to the strong tape material and strips that crossed the ankle.^[26]

NH cannot be used alone, as the shape of the arc is roughly triangular, which indicates a relationship between arch length and arch height.^[23] Hence, NH divided by foot length or truncated foot length was suggested. However, a recent study reported that no significant relationships between arch height and foot length exist.^[43] Furthermore, various methods of measuring NH are available^[44–47]: nonweight bearing, 50% weight bearing, and 100% weight bearing, which could be associated with the significant difference among the taping conditions only during sitting and jogging in this study.

A high ND was associated with the development of sports-related injuries in the lower extremities.^[48,49] A previous study showed that at the stance phase of running, a high ND could be associated with increased peak ankle and knee joint moments, which in turn may lead to lower extremity injuries.^[50] Moreover, as static measures of ND have poor association with dynamic measures^[51] because only sagittal plane movement is taken into account,^[52] dynamic navicular assessment may be an effective tool to examine foot function affected by extrinsic and intrinsic factors in walking and running.^[53] Therefore, in this study, ND was measured during weight bearing, walking, and jogging; nevertheless, a significant difference among the taping conditions was not found. In addition, in healthy elite athletes, the measured ND after the taping tended to be less than the values reported in a previous study. A high arch, <4mm ND, is known to absorb energy poorly^[54]; thus, taping to restrict ND in healthy athletes may require special attention. Furthermore, ND should be normalized to the foot length to be a valid measure of pronation^[52] given that NH is influenced by foot length.^[23] Therefore, the typical range of normalized ND will be needed for providing detailed and useful information on preventive strategies of sport-related injuries in the lower legs.

The PP provides an indirect representation of subtalar joint movement, which determines the amount of pronation occurring at the subtalar joint.^[29] The emed systems are among the most commonly used clinical tools for barefoot pressure measurement in humans worldwide,^[24] and interrater reliability correlations of this system were >0.70.^[55] Lange et al^[56] demonstrated that Low-Dye taping increased peak PP values under the lateral midfoot and under the toes in subjects with >10mm ND, and Vicenzino et al^[57] showed that Low-Dye taping increases lateral midfoot PP. Aguilar and Merino-Marbán^[32] suggested that KT may be of help to clinicians in the short-term correction of pronated foot posture by using a plantar platform. However, the tape's initial effect of reduced peak PP over the lateral midfoot was lost after a 10-minute walk.^[37] Our study showed that the differences in peak PP among the taping conditions were insignificant during standing, walking, and jogging, which may also be related to the participants' unnatural movement during the experimental procedure.

The results of this study showed that RT could control the decreased NH during jogging. The findings also suggested the RT applied to the lower leg could prevent and treat MTSS by reducing a potential risk factor. However, only healthy elite athletes were included in this study and the acute effect of sports taping was identified. Thus, future studies should incorporate a

randomized control trial design and investigate whether these differences exist in sports-specific maneuvers and/or few days after its application. Furthermore, as the foot of patients with MTSS may have a faster rate of medial plantar loading,^[58] a future study identifying the amount of pronation and the velocity of ND would provide more valuable evidence for the prevention and treatment of MTSS.

5. Conclusion

This study showed RT technique maintained the NH during sitting and jogging. On the basis of these results, RT technique could be an effective preventive and treatment strategy for MTSS.

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