ANALYSIS ON THE EFFECTS OF WARM UP ON ANKLE JOINT MOTION AND STRIKE PATTERNS FOR 50M SPRINT PERFORMANCE.

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The purpose of this study was to analyze the effects of ankle angles and strike pattern on 50m sprint test performance for young non-athletes. Twenty-seven non-athletes were distributed in a control group (CG) and an experimental group (EG), and performed pre, control and post 50m sprint tests. Motion analysis data from the left leg ankle angle (LAA), right leg ankle angle (RAA) and strike pattern were obtained during landing moments in the sagittal plane using video recording. In accordance with our findings, basic sprint drill warm-ups can improve sprinting time in young girls and contribute to the strengthening of ankle muscles and joints. Motion analysis of strike pattern and ankle joint motion during sprinting tests and the implementation of warm-ups with basic sprint exercises could help in the recognition of range of motion in ankle joints, reduce the risk of injury, and benefit sprint performance.

KEYWORDS: fitness test, midfoot strike, dorsiflexion, running kinetics

INTRODUCTION: Young non-athletes are evaluated annually by physical education (PE) teachers and sport coaches in fitness tests at high schools. They usually perform 50m sprint tests which require output explosiveness, maximum velocity, coordination and an adequate strike pattern to achieve positive results. Consequently, kinematics of strike pattern has become an important variable that is studied and related to sprint performance and injury prevention (Souza, 2016) in young non-athletes or athletes. Coaches and teachers can use motion analysis tools to observe the range of motion of kinematic variables. In the case of running, foot positioning at initial and final contact with the ground were studied previously (Almeida, Davis & Lopes, 2015). The use of advanced technology and biomechanics equipment to analyze kinematic variables in students or athletes performing fitness tests in PE class and youth sport training could be difficult to implement in athletics and PE departments. However, motion analysis using video cameras, iPads and sports apps that have slow motion functions and drawing tools are available nowadays and permit the observation of whole body movements and the ability to focus on upper and lower limb movements in sport-specific performance. In relation to motion analysis for sprint performance, there are studies that focused on knee and ankle joint kinematics identifying abnormal biomechanics, foot positioning, stride angle and strike pattern on running economy (Santos-Concejero et al., 2014) as well as the effect on performance.

Our study supports that ankle joint positioning and strike pattern at initial contact with the ground could have positive effects in sprint tests performance, particularly if subjects learn specific sprint drills for warm-up before testing. As evidence, researchers determined the following strike patterns: rear foot strike (RFS), midfoot strike (FS) and fore-foot strike (FFS). Their findings demonstrated that FFS resulted in a plantar-flexion ankle position (Kuhman Melcher & Paquette, 2016) mostly used by young, professional sprinters. However, FFS is not commonly observed in young non-athletes. This aspect could be related to lack of practice of basic sprint running exercises, lack of sprint training experience or limited opportunities to improve their running kinematics. Ankle plantar flexion is considered vital for maximal sprint speed. (Lai, Schache, Brown & Pandy, 2016). In addition, dorsiflexion ankle position during initial contact to the ground has negative effects on sprint performance. Although researchers found no interaction between foot strike and speed, they still support the position that kinetic characteristics can help to control running injuries (Kuhman et al., 2016).

The purpose of this study was to analyze the effects of ankle angles and strike pattern on 50m sprint test performance in young non- athletes and to compare groups with two different warm-up protocols in PE class and their respective efficacy in running kinetics. In this study, left ankle angle (LAA) and right ankle angle (RAA) and strike pattern data were obtained to determine possible changes in running kinematics. We hypothesized that leg ankle angle and RFS strike pattern would negatively affect or influence sprint tests performance in young non-athletes.

METHODS: This study followed twenty-seven young non-athletes (mean age, 15.33 ± 0.55 years). Their mean height and body weight were 170.74 ± 7.58 cm and 62.63 ± 17.88 kg. The subjects were informed of the experimental procedures and the study was approved by the Academic Committee of the High School.

Procedures: For data collection, subjects were distributed in two groups: a control group (CG) and experimental group (EG). Both performed 50m sprint pretests (PT) in the first week, control tests (CT) in the fourth week and posttests (PCT) in week eight. Motion analysis data was collected using a myDartfish 360S App camera, an iPad Pro 10,5 inches with iOS 11.3, and a 1.5m aluminum tripod with calibration at 90 degrees. The angle of the camera was adjusted to a horizontal position at 90 degrees in front of the track. The location of the camera was 25m from the start line and at a distance of 7.80m from the line of the third track. This location allowed researchers to record three complete running phases (landing, flight moment, take off) for the left and right leg of all the subjects. Time was recorded using a hand stopwatch. The teacher used a whistle at the start and finish of the 50m sprint test while other teachers recorded videos using the whistles as cues to start and finish recording. Subjects were asked to run at maximum speed from the middle start position.

Protocols: The experimental group (EG) was instructed to warm up for 10 minutes using basic sprint drills in the following order: ankle bounce drill, high knees, butt kicks, single arm bounding. The subjects completed 2 sets of 3 reps at a distance of 30m. The subjects were encouraged to perform drills using correct techniques after warm-ups after which they continued with PE class as usual. The control group (CG) was instructed to perform a 10 minute warm-up that included habitual exercises used in PE class such as jogging, static and dynamic joint exercises (flexion, extension, rotation, inversion, and eversion, 8 reps or 8 seconds). Both EG and CG groups had two classes/week. The subjects were evaluated three times in a 50m sprint test and performed with maximum velocity. The pretest was performed in the first week, the control test in the fourth week and the posttest in the ninth week.

Kinematic Analysis: LAA, RAA and strike pattern data was obtained using myDartfish 360S App measure tools. Videos were analyzed using still shots at 1/8 frames per second. Data was obtained for all subjects in the three tests. To standardize and determine the measure for ankle angles, the measure angle tool was used in the direction of the lateral malleolus along the fibula and finishing at the knee joint, and from the calcaneus to the fifth metatarsal. LAA, RAA and strike patterns were collected during landing moment in the sagittal plane, as well as comparisions between groups and the effects at 50m sprint performance. All the data was collected from left and right ankle landing positioning in two complete phases of running captured at 25m. Ankle angles and strike patterns were included for data analysis only in one complete phase of landing, take off and flight time moments in pre (PT), control (CT) and posttest (PST).

Statistical Analysis: With software myDartfish 360S camera 2D video recording of the subjects, this study analyzed the following variables: LAA and RAA, RFS, FS and FFS strike patterns in PT, CT and PST. Age, gender, height and weight were also included for data analysis. The obtained data was analyzed using descriptive statistics (mean ± SD) and Multi-factor ANOVA SPSS Statistics® software version 25, with a statistical significance $p \leq 0.05$.

RESULTS: Twenty-seven subjects met the inclusion criteria. Two different warm ups were used in this investigation and multiple comparisons between subjects were realized showing statistical significance as follows: EG and CG groups produced statistical significance (p<0.001) in 50m sprinting time. The comparison between test, time, LAA, RAA did not produce statistical significance (p>0.05) in contrast. Gender produced statistical significance (p<0.05) in sprinting time.

Table 1. Leg ankle angles, time and groups mean and standard deviation.

	GROUPS	Mean	Std. Deviation	N
LAA	EG	88.10	7.80	42
	CG	88.53	5.34	39
	Total	88.31	6.69	81
TIME	EG	9.62	1.14	42
	CG	8.43	1.31	39
	Total	9.04	1.36	81
RAA	EG	93.06	7.13	42
	CG	90.91	5.96	39
	Total	92.03	6.64	81

Left strike patterns (LSP) and right strike patterns (RSP) did not produce statistical significance (p>0.05) in tests. In addition, RFS and FS were highly predominant for all subjects during the three tests.

DISCUSSION: The subjects perform 50m sprint tests for a National Fitness Test, which is a yearly evaluation and represents an essential physical standard for youth (Rumpf, Lockie, Cronin & Jalilvand 2016). Sprint test performance can be developed by adequate running technique and correct lower limb joint motion. Several researches have demonstrated how warm-up protocols before fitness testing can have an influence on sprint performance. As well, authors have analyzed advantages of correct ankle, knee and hip kinetics to improve sprinting time, although in this study two different warm-ups produced a statistical significance between time and gender, and a statistical significance between time and EG and CG. Moreover, other aspects could influence or be related which supports evidence that different training programs and warm-ups can be effective for non-athletic subjects (Prieke, Kruger, Aehle, Bauer & Granacher, 2018), especially those warm ups that include basic or specific drills for improving sprinting.

In relation to running technique, the subjects with an RFS pattern could experience a braking impulse in running, and experience injuries related to ground reaction forces and uncontrolled joint kinetics (Souza, 2016). Previous research has compared RFS with FFS in sprints and their findings show that strike patterns can influence sprinting performance. Foot positioning and ground reaction force at initial contact could also provoke abnormal knee and hip kinetics, with a high possibility of injury. Despite this, the absence of impact peak in the ground force reaction with an FFS strike compared with an RFS strike could help to reduce injuries (Kuhman et al., 2016). Implementing basic sprint drills that induce FFS in place of RFS with non-athletes might improve running technique and prevent injuries. Otherwise, the incidence of FS (LSP 64.2%, RSP 70.4%) is higher than RFS (LSP 30.9%, RSP 24.7%) in our study. Additionally, in relation to the number of strike patterns observed at PT, CT, and PST, findings show that FS has a higher frequency for both EG and CG. RFS was second in frequency and FFS was observed just 4 times for LSP and 4 times for RSP in the EG. Thus, an FS strike pattern was predominant for both groups and in all tests. The authors have already described that ankle angles are related to strike patterns and the effects of impacts in running injuries. As an example, transitioning from RFS to FFS may not offer protection against injuries because FFS and RFS had similar ground reaction forces (Boyer, Rooney & Derrick, 2014). Although there is still no evidence when transitioning from RFS to FS, notwithstanding that the FS pattern was predominantly higher in both CG and EG groups during PT, CT and PST in this study. Strike patterns did not produce statistical significance between EG and CG, supporting similar information that demonstrates no advantage for strike patterns in running. On the other side, authors suggest FFS could be favorable for subjects with knee joint injuries and RFS for unstable ankle and knee joints (Knorz et al., 2017). The frequency observed in RFS from EG and CG would be produced by unstable ankles as was mentioned before but also could affect sprinting performance. As for ankle and knee joint injuries prevention, stability and balance exercises can develop an adequate ankle angle at initial contact with the ground, increase knee joint support, and consequently improve sprint performance. Another study reported that ankle dorsiflexion is commonly observed during RFS and can be produced by midsole hardness or surface stiffness (Hardin, Van Den Bogert & Hamill, 2004). It could also affect the normal range of motion of the ankle. Basic sprint drills like ankle bounce drills contribute to plantar flexion increasing FS or FFS initial contact with the ground. Heel lifts can also reduce patellofemoral joint stress but do not have associated changes in step length or frequency, consequently they may have therapeutic benefits for runners with knee joint injuries (Mestelle, Kernozek, Adkins, Miller, & Gheidi, 2017). Plantar flexion exercises oriented for non-athletes can decrease knee injuries. However, the relation between the effects of these exercises in warm-up protocols or training programs that produce changes in RFS to FS or FFS for non-athletes, still needs to be analyzed. Besides, FFS demonstrated lower patellofemoral contact force and stress compared with heel strikes. The ankle at FFS showed higher plantarflexion moment ($p= 0.001$) and Achilles tendon force ($p=0.002$) compared with RFS. On the other hand, the increase of ankle plantarflexion and Achilles tendon loads could increase the risk of ankle and foot injuries (Kulmala, Avela, Pasanen & Parkkari, 2013). This aspect will be a useful consideration for coaches and teachers working at non-athlete training levels and likewise for specific fitness tests or sports. In our study, the higher presence of a FS strike pattern obtained from motion analysis demonstrates that the subjects from both groups habitually perform dorsiflexion during initial contact, maximizing the ground force and the possibility of developing knee or ankle joint injuries. At the same time, increased loading at the ankle joint for FFS should be a concern for subjects who are attempting to alter their strikes patterns (Rooney & Derrick, 2013). To make adjustments to strike patterns, the basic sprinting drills can be a simple and quick way to correct foot positioning. It would also be necessary to detect which muscles and tendons individually require more specific drills to increase strength and improve running technique.

Studies suggest that a very high inclination ankle angle at initial contact may not be advantageous, and that ankle angle is necessary for sprint technique analysis. The authors demonstrated that the ankle joint has a significant effect in the 30m sprint, minimizing running time, when an adequate level of motion with respect to the sagittal plane is required (Struzik et al., 2016). In relation to this aspect, our study analyzed the relationship between leg ankle angles during initial contact at sprint performance. LAA and RAA did not produce any statistical significance with respect to time. However, basic sprint drills produce a different ratio of ankle joint motion. Furthermore, an adequate level of motion is associated with strike patterns. Hip and knee joint angles are attached with ankle positioning at initial contact and the complete cinematic chain can have an influence in maximal speed. For this reason, dynamic exercises that can develop strength for ankles, knees and hip joints are necessary. In this way, the complete lower limb cinematic chain is able to produce smooth ankle joint motion. Although LAA and RAA did not produce statistical significance between time and tests, similar evidence was collected in another study where after resistance training intervention decreased sprinting performance (Bolger, Lyons, Harrison & Kenny, 2015). Nevertheless, the use of adequate, basic sprint drills in warm-ups could support the development of muscle strength and joint stability for sprinting performance. On the other side, ankle angles did not produce statistical significance between EG and CG. Moreover, to improve the time in sprinting tests, basic sprint drills such as ankle bounces and high knees would contribute to optimal leg ankle angles, foot positioning and technical movements for non-athletes. Warm-ups can also include agility and strength skills, and specific sprint exercises. Drills should be easy and quick to perform for novices and be implemented during PE warm-ups. The authors consider strength to be related to sprinting performance (Cronin & Hansen, 2015). Regarding this aspect, basic sprint drills contribute to improving the strength of plantar flexion muscles (such as the gastrocnemius, soleus and plantaris). The drills produce adaptations in the range of motion of leg ankle angles for better foot positioning and a more economical use of energy and generate better running kinetics which facilitates high intensity running (Darall-Jones, Jones, & Till, 2016).

As it is known, basic and specific sprint drill warm-ups are usually applied to young athletes who sprint to develop an appropriate technique for running. They can produce positive effects and benefit sprint performance (Lockie, Murphy, Schultz, Knight & Janse de Jongse, 2012). High knees and especially single leg bounding drills demand high impact on the leg and ankle. In addition, footfall patterns in the landing moment require an adaptation to meet energy requirements (Amado, Jewell, van Emmerick & Hamill, 2017). For this reason, muscles and ligaments require preparation and early strength conditioning programs. For youth focusing on their leg and ankle muscles these programs can contribute to the pursuit of this objective. Otherwise, the findings of the effects between EG and CG and time demonstrated a statistical significance: CG sprint time average was 9.62 ± 1.14 s and EG was 8.43 ± 1.31 s. This assumed that EG sprinting time was slower than CG, while EG and CG ankle angles and strike patterns had no significant effect in sprinting time. Moreover, sprinting times were significantly better when variables were analyzed separately by gender. Findings revealed that EG girls were 0.08s faster in comparison to CG girls in the 50m test time average during the CT and PST tests. As well, the male sprinting time average of 7.89 ± 0.72s was faster than the female time of 9.97 ± 0.99s. No statistically significant differences were found between EG and CG sprinting time and PT, CT or PST. According to our findings, basic sprint drill warm-ups can improve sprinting time in young girls and contribute to strengthening ankle muscles and joints. Studies in relation to gender maturation, joint kinetics and muscle fibers types in high performance youth could be considered as an analysis topic for future research.

CONCLUSION： This study identified that through video motion analysis, PE teachers and coaches analyzed 50m sprint performance and observed running kinetics. This style of analysis can be implemented as a teaching/coaching tool in PE classes or training sessions and it can also enhance the understanding of range of motion of ankle angles, and the influence of strike patterns in sprinting performance. Adequate warm-ups that include basic sprint exercises can develop strength, balance, velocity and other capacities involved in improving fitness performance. Ankle angles at initial contact with the ground can produce a high impact and ground reaction force, increasing the possibility of ankle joint injury when lower limb muscles or ligaments of non-athletes are not strengthened before performance tests. RFS and FS were the higher number of strike patterns observed. These strike patterns can affect the normal range of motion for ankle, knee and hip joints. For this reason, observing and evaluating strike patterns for leg and ankle joints during sprinting and the implementation of basic sprinting exercises in warm ups or training sessions oriented to correct strike patterns can help to modify the range of motion for ankle joints, reduce injury risk, enhance running kinetics and improve sprinting performance.

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