THE EFFECT OF WARM-UP ON SPRINTING KINEMATICS

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The purpose of this study was to verify the effects of warm-up on kinematic variables during short distance repeated sprints. Twenty-two college students randomly performed 2 x 30-m running time-trials after warm-up or with no warm-up, in different days. Performance (time-trial) and biomechanical (step length and step frequency) were assessed during both repeated trials. Performance was 0.5% faster after warm-up in the first 30-m time-trial (p = 0.03, *d* = 0.44), but without differences on step length and frequency. The second sprint was not different between conditions, but it was better than the first sprint in the no warm-up condition. This condition also led to higher changes between the first and second sprint. Thus, the warm-up is suggested to improve maximal running performances and maintaining kinematics more similar throughout the sprints.

KEY WORDS: pre-exercitation, running, length, frequency.

INTRODUCTION: Warm-up is usually assumed to be the first part of physical activity and it is accepted to be fundamental to enhance the performance and prevent injuries. Despite the limited evidences demonstrating its efficacy, the scientific community supports the use of warm-up as a preparing activity (McGowan, Pyne, Thompson & Rattray, 2015). It has been suggested that the rise in muscle temperature caused by the priming exercises results in multiple physiological and metabolic changes, and is the major contributing factor to positively influence performance. Simultaneously, some recent research found different biomechanical responses to the use of warm-up in swimmers (Neiva et al., 2014) and an effect of warm-up on acute motor learning and on sensorimotor responses that led to different biomechanical movement patterns after different swimming warm-ups (Neiva et al., 2016). Specifically in running, most of the studies focused on performance and physiological variables without the full understanding of the effects of warm-up. In fact, there is a scarcity of knowledge about the effect of warm-up on the biomechanical variables of running and that could be critical to training and performance. In recent years, warm-up has emerged as one of the main concerns to coaches, athletes and researches, evidenced by the increase in publications about this subject. This novel focus analysis of the biomechanical effects could provide useful information for performance optimization. Thus, the purpose of this study was to analyze the effect of warm-up on the kinematics of short running sprinting performance.

METHODS: Twenty-two male college students volunteered to participate in this study (mean ± SD: 19.32 ± 1.43 years of age; 1.76 ± 0.67 m height; 68.48 ± 9.91 kg body mass). After local ethics board approval, ensuring compliance with the Declaration of Helsinki, the participants were informed about the study procedures, and a written informed consent was obtained from the subjects. All the procedures took place at the same time of the day (14h-18h PM) at a multi-sport indoor facility (more than 50m long). The study followed a repeated measures design. Each participant completed 2 sessions of 2 maximal 30-m sprints, in randomized order, separated by 48h. They were reminded to maintain the same diet and activity routines during all the procedures.
After arriving facilities, each participant remained seated for 5min to rest and concentrate on the procedures. Then, they were assigned to each protocol (standard warm-up or without warm-up). The standard warm-up was designed based on research (McGowan et al., 2015) and with the help of an experienced coach, and comprised 5min of easy run, 5min of drills

and then 2 short distances of progressive running speed. Following the warm-up, participants rested for 5min (seated) and then 2 time-trials of 30-m running were performed with 5min of interval between. The sprint times were recorded using Brower equipment (Wireless Sprint System, USA). All the procedures were recorded by two video cameras (Casio Exilim Ex-F1, f=30Hz) placed perpendicular to the running track. For each run of each subject, the average step length (SL) and step frequency (SF) over the whole 30-m distance were analysed. The total number of steps taken in the race by each of the subjects was counted using the Kinovea® software (version 0.8.15) and SL and SF were derived from that, knowing time and distance performed.
Standard statistical procedures were selected for the calculation of means, standard deviations (SD) and 90% confidence interval. The normality of all distributions was verified using Shapiro-Wilks tests. To compare data between two trials, Student's paired t-tests (parametric) was used and the alpha level was set at $p < 0.05$. Cohen's *d* effect size was determined and 0.2 was considered small, 0.5 medium, and 0.8 large (Cohen, 1988).

RESULTS: Performance was significantly better in the first sprint after warm-up than without warm-up, while no differences were found in the second 30-m time-trial (Table 1). In Table 1 are shown that, in both sessions, there were no differences between the biomechanical variables between using and not using a previous warm-up.

Table 1
Mean ± SD of performance and biomechanical variables in 30-m run. Significance (p-value) and effect size (*d*) are presented (n=22)

	Without warm-up	With Warm-up	Mean Difference	p-value	*d*
1st 30-m (s)	4.67 ± 0.20	4.58 ± 0.20	-0.5%	0.03	0.44
2nd 30-m (s)	4.60 ± 0,23	4.56 ± 0.22	-1.0%	0.27	0.17
1st Step frequency (Hz)	4.27 ± 0.25	4.31 ± 0.25	1.7%	0.54	0.16
2nd Step frequency (Hz)	4.29 ± 0.31	4.30 ± 0.18	2.6%	0.86	0.04
1st Step length (m)	1.51 ± 0.06	1.52 ± 0.07	2.2%	0.38	0.15
2nd Step length (m)	1.53 ± 0.08	1.54 ± 0.07	1.5%	0.65	0.13

There were differences in time between the first and the second 30-m sprint when no warm-up was performed before ($p = 0.008$, $d = 0.32$). No significant differences were found between the first and the second sprint in the other variables. However, without warm-up the changes were always higher than with warm-up. These changes between first and second time-trial are presented in Figure 1. Note that the 30-m sprint were calculated based on time, which means that the higher the improvement, the lower the values of change.

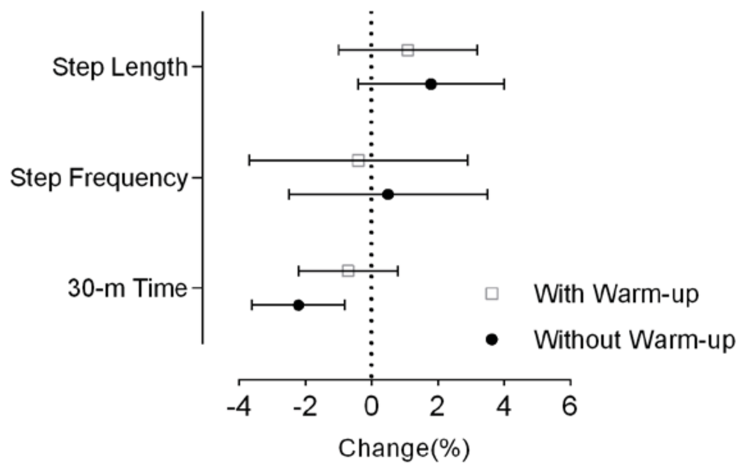

Figure 1: Mean changes (± 90% CI) between the first and second 30-m sprint with and without warm-up.

DISCUSSION: The aim of this study was to verify the effects of a standard warm-up protocol on the 30-m repeated sprint performance and to analyse the effects on the running SL and SF variables. The main finding was that performance was improved after warm-up comparing to no warm-up condition. However, this difference was not reflected on the SL and SF analysed. Still, we could verify that there was a tendency to maintain the values from the first to the second sprint in all variables. This could indicate a maintenance of the technical aspects of the run after warm-up, revealing the importance of a proper warm-up before sprints and repeated sprints performances.

In competition or training venue, the runners are used to complete any kind of active warm-up to increase their preparedness to the subsequent activity. Despite this usual practice, there is a lot to know about the real effects of warm-up in the different components of the performance, such as physiological and biomechanical. To the best of our knowledge, only one research focused on the biomechanical changes of running caused by warm-up, analysing shoulder lean, hip flexion and forward lead with improved positions but without improved 36.6 m performances (Smith et al., 2014). On the contrary, our results showed better sprint performances after warming-up but without kinematic changes. In fact, the positive effect of warm-up in sprint was already widely evidenced in recent years (McGowan et al., 2015), and our results agreed. However, we may be expecting that SL and SF could differently respond to the different level of preparedness as literature suggested in other sports (Neiva et al., 2014). Perhaps, this similarity could be explained the low level of the subjects, once elite runners perform more efficiently than less experienced runners (Padulo et al., 2012). Even so, the results revealed a propensity for a higher SF and SL in the warm-up condition, in the first sprint, where the differences in performance were significant. Runners adapt their optimum SL and SF to get the most efficient running for the speed performed and according to their own characteristics (Salo, Bezodis, Batterham & Kerwin, 2011). The inexistence of significant differences could be caused by the individual kinematic responses to the conditions tested trying to obtain the best result. Perhaps a 3D motion capture system could allow a better knowledge of the biomechanical changes for our results. Knowing this and based on these results, we can suggest further research on the changes in technical pattern of runners according to the warm-up previous performed.

The second sprint led to no different performances between conditions. As expected, the first sprint may have worked not only as a warm-up for the unheated condition, but also as an enhancer of performance, increasing the neuromotor excitability that can optimize performance in a second sprint (Spencer, Bishop, Dawson & Goodman, 2005). Actually, the minor changes from the first to the second sprint were verified when warm-up was done. We could suggest that fewer changes in technique occur in this condition. This could mean a better preparedness for maximal running and lower influence of fatigue in the second sprint that could cause changes in running kinematics.

CONCLUSION: This study revealed the importance of warm-up to maximize short distance running performance. In fact, the use of a standard warm-up led to better performances in the first one of the two sprints. However, it seems that a standard warm-up did not result in more than small effects in SL and SF compared to the no use of warm-up. Even so, the results tend to change more from the first to the second sprint when there was no warm-up. Our findings could be useful for coaches, as there were clear evidences that warm-up is beneficial to performance and it was showed that the running performance and running technique seems to be more stable when a warm-up is accomplished before maximal repeated sprints. Coaches should focus on the use of a proper warm-up that can maximize performance and sustain technical aspects, perhaps delaying fatigue. This is especially relevant during training sets where several repetitions of maximal efforts are performed. To the best of our knowledge, this was the first investigation trying to understand the changes in SL and SF in running, specifically in short sprints, and further research should developed to better understand the most appropriated warm-up to optimize running performance.

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