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Original Article

Absence of effect of step straightness on sprint running performance, kinetic and kinematic characteristics

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Abstract:
A 100 m race is essentially running from point A to point B as quickly as possible, thus, deviations from a straight linear path may cause performance detriments. This study elucidates the importance of running straight during linear sprinting. A new descriptive characteristic of sprint running (step straightness) was defined and measured, representing the mediolateral distance of step-to-step centre of pressure foot position relative to the centre of an athletic track lane. The mediolateral distance away from the middle of a running lane (step straightness) is an indicator of deviating from a straight linear sprint path.The purpose was to clarify whether step straightness is a determinantof performance, kinetic and kinematic sprint characteristics during the initial, middle, later and total acceleration phase sections. Eleven sprinters and thirteen baseball players performed 60 m maximal effort sprints over a long force platform system. Step-to-step ground reaction force was used to calculate step straightness, running speed, step length, step frequency, support time, flight time, step width, mediolateral positive impulse, mediolateral negative impulse, mediolateral net impulse, propulsive impulse, braking impulse, anteroposterior net impulse and effective vertical impulse. Pearson correlations demonstrated nostatistically significant ($P > .050$; trivial–moderate effects) associations between step straightness and any performance, kinetic or kinematic variables measured, suggesting that step straightness is not a performance determinant. It was concluded that there may be no practical importance of straightness during linear sprinting.The practical implication of this study was clarifying that there may be no need for coaches to encourage the straightness of running during linear sprinting or for athletes to concentrate on their body position in a lane relative to straightness.
KeyWords: Step width; Centre of pressure; Over-line sprinting;Linear sprinting;Ground reaction force; Spatio-temporal.

Introduction

A 100 m race is essentially moving the body in a straight line as quickly as possible. Deviating from a linear path during sprint running may result in small timing or performance magnitude detriments, due to increasing resultant distance travelled. Straightness may be important for performance in other linear racing sports such as rowing (Smith & Hopkins, 2012), however, the importance during over-ground running is unknown. Therefore, defining straightness as a descriptive sprint characteristic and measuring the relationship between straightness and performance or other sprint characteristics may be of interest to coaches and athletes, considering a 100m race can be decided by a.001 s difference(Majumdar & Robergs, 2011; Slawinski et al., 2017). Previously, clarifying determinants of sprint performance, such as kinetic and kinematic characteristics, has bettered the understanding of technique during different phases of accelerated sprinting and improved best practice recommendations for sprint training prescription (Gleadhill & Nagahara, 2020a; Murata et al., 2018; Nagahara et al., 2014b). A new sprint characteristic named step straightness (SS) is defined here as the average mediolateral distance between step-to-step foot centre of pressure and the middle of an athletic track lane.

Another more well-known and well-researched sprint characteristic is step width (SW), measured previously with force plates as the mediolateral distance between foot centre of pressure for consecutive steps (Nagahara et al., 2017). In a 100m race, SW is greatest at the first step (0.39±0.07 m) and decreases gradually before levelling out (0.17 ±0.04 m) (Ito et al., 2006). Previous research demonstrated that wider SW was associated with greater running speed (RS) and mediolateral impulses over 52 m of sprinting (Nagahara et al., 2017). Wider SW may be associated with greater propulsive force, possibly through increasing adductor muscle activity (Nagahara et al., 2017; Wiemann & Tidow, 1995). In addition, wider SW may result in larger glute activation during the support phase to stabilise the pelvis from greater hip range of motion associated with wider SW (Sandamas et al., 2019, 2020).The SW is measured relative to contralateral foot positions, in comparison to

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SS being relative to an external fixed axis (middle of the lane). However, both SW and SS are similar in terms of measuring mediolateral distances. Moreover, previous SW research has controlled for athlete height to standardise the influence of differences in height among a cohort, by expressing the ratio of SW to height as a percentage(Nagahara et al., 2017). Therefore, SS research should incorporate the same height control measure.

Although the above research betters the understanding of SW as a determinant of accelerated sprint performance, no research has focused on mediolateral movement relative to an external marker within a lane, namely, the influence of SS is a new novel field of sprint research.The purpose of this research was to elucidate whether SS is a determinant of sprint performance during the acceleration phase and clarify the association of SS during maximal effort sprinting to kinetic and kinematic variables. Due to previous research demonstrating that SW (Nagahara et al., 2017) and other kinematic characteristics (Gleadhill & Nagahara, 2020a) are determinants of performance during different sections of acceleration, it was hypothesised that SS would be statistically significantly associated with RS. In addition, it was further hypothesised that SS would be statistically significantly associated with SW, due to the similarity of measurement methods (both mediolateral distances).

Material & methods

Participants

Two separate groups, one group of trained sprinters (minimum sprint training age of four years) and one group of baseball players (no sprint training age), volunteered to participate. The groups were separated for statistical analysis due to the difference in sprint training age/expertise. Group one (sprint trained group) included 11 male sprinters from a university athletics club (mean±SD: age, 20.1±1.4 years; height, 171.6±5.5 cm; body mass, 68.5±2.9 kg; 100 m personal best time, 11.0±0.1 s). Group two (untrained group) included 13 male baseball players from a university baseball club (mean±SD: age, 19.4±0.9 years; height, 173.0±6.1 cm; body mass, 74.6±5.3 kg). Differences in sprint characteristics between the trained and untrained population was not the focus of this research, thus, no between group analysis was completed. The research was approved by the institutes ethics committee and written informed consent was obtained from each participant prior to experimentation.

Procedure

After self-selected warm up, each participant completed three separate 60 m maximal effort sprints with a minimum recovery time of 10 minutes(Holmyard et al., 1988; Nagahara et al., 2018b). The first trial was a control 60 m maximum effort sprint.After the control, an 80 m straight line was made with white tape on the surface of the athletic track in the centre of the lane (also the centre of force platforms). Two maximal effort 60 m sprints were completed over this line. These trials were defined as over-line sprinting (OLS), completed to elucidate if any SS associations with performance, kinetic or kinematic characteristics changed (in comparison to during control sprints) due to participants concentrating on straightness. During OLS trials, participants were instructed to sprint maximally while maintaining the same technique as during the control sprint. The OLS instructions were to keep the centre of mass or middle of the body directly over the top of the straight centre line, and to visually focus on the line beneath them during initial acceleration and 20 m in front of them after the head naturally reached a more upright position. Essentially, participants were asked to focus on running straight in reference to a visual training aid. Visual training is typically used in sporting environments to improve situational processing ability and responses, thereby improving performance (Appelbaum & Erickson, 2018). Start techniques included block clearance (trained group) and three-point starts without blocks (untrained group), which were both excluded from analysis.An electronic starting gun was used to begin trials (which acted as the trigger for data collection), with the 'on your marks' and 'set' cues. Participants wore their own athletic attire and spiked race shoes (sprinters) or baseball training shoes (baseball players). Wind conditions were controlled for by using an indoor athletic track ensuring a negligible wind effect. All three trials were performed on a synthetic athletic track covering a 50 m long force platform system (sampling frequency set at 1000 Hz) consisting of 54 force platforms (TF-90100, TF-3055, TF-32120, Tec Gihan, Uji, Japan) connected to a single computer (Nagahara et al., 2018b). A distance of 60 m was chosen for trials to ensure participants did not begin to intentionally slow down, running over the entire measured length with maximal effort.

Statistical analysis

The control and the fastest trial of the two OLS trials was used for analysis per participant based on average RS. Raw ground reaction force was filtered with a digital fourth order 50 Hz low pass Butterworth filter(Clark et al., 2017; Nagahara et al., 2017).Exceeding or falling beneath a vertical ground reaction force of 20 N was set as a threshold, to identify step-to-step foot strike and toe-off instants. Step duration was measured as the time between foot strikes of contralateral feet and step frequency was calculated as the inverse of step duration. Step-to-step support time was calculated as the duration of foot contact with the ground (foot strike to toe-off) and flight time was the duration of neither foot contacting the ground (toe-off to foot strike). Centre of pressure was defined as the location of ground contact at the middle of each support phase (mean centre of pressure for 0.01 s during the middle of the support phase) and step length was calculated as the anterior distance between centre of pressure locations of contralateral steps. The RS was calculated as the product of step length and step frequency. The SW was calculated as mediolateral distance between centre of pressure locations of contralateral steps(Nagahara et al., 2017).The centre of each force platform was located in the centre of the athletic track lane (mediolateral direction), thus, the centre of pressure distance (COPd) was calculated as the mediolateral distance between step-to-step centre of pressure foot location and the centre of the force plates. The SS was calculated as the moving average (1^{st}–2^{nd} step average, 2^{nd}–3^{rd} step average and so on) of COPd, and SS defined as the average mediolateral distance between step-to-step foot centre of pressure and the middle of an athletic track lane.

To control for participant height differences, the ratio of SS to participant height was calculated as a percentage, in accordance with previous research (Nagahara et al., 2017). Time integration of vertical force, positive anteroposterior force and negative anteroposterior force were used to calculate the vertical, propulsive and braking impulses during each support phase, using the trapezoid formula. Net anteroposterior impulse was calculated as the sum of propulsive (positive values) and braking (negative values) impulses. Effective vertical impulse was calculated by subtracting body weight from vertical force and then integrating with respect to support phase duration(Morin et al., 2015; Weyand et al., 2000). Mediolateral impulses were calculated in the respective directions, standardised to positive and negative values respectively due to being bilaterally opposite(Nagahara et al., 2017). Net mediolateral impulse was calculated as the sum of medial (positive) and lateral (negative) impulses.

All measured step-to-step sprint characteristics for each participant were further grouped to represent the initial acceleration phase (1^{st}–4^{th} step average), middle acceleration phase (5^{th}–14^{th} step average), later acceleration phase (15^{th} step–step before maximum RS was reached average) and the total acceleration phase (All steps), according to previous research (Nagahara et al., 2014a, 2020). Further descriptive characteristics calculated included standard error and two step moving averages. All statistical analysis was completed separately on both groups (trained and untrained group). Pearson correlations were calculated to compare the relationship between SS and 13 separate sprint characteristics, including RS, step length, step frequency, support time, fight time, SW, mediolateral positive impulse, mediolateral negative impulse, mediolateral net impulse, propulsive impulse, braking impulse, anteroposterior net impulse and effective vertical impulse(Gleadhill & Nagahara, 2020b; Morin et al., 2015; Nagahara et al., 2018a; Nagahara et al., 2014b; Rabita et al., 2015). Each of these sprint characteristic comparisons were completed separately for every phase (initial, middle, later or total sections), for each trial (control or OLS trials), and for both groups (trained and untrained).

Therefore, 208 separate Pearson correlations were calculated to clarify relationships with SS (13 sprint characteristics × four sections × two trials × two cohort groups). Significance level was set at $P < .050$. Threshold values for the interpretations of correlation coefficient were < 0.1 (trivial), 0.1–0.3 (small), 0.3–0.5 (moderate), 0.5–0.7 (large), 0.7–0.9 (very large) and >0.9 (extremely large) (Hopkins et al., 2009).

Results

Descriptive characteristics including means and standard errors were plotted to visually represent both cohort results (Figure I and Figure II and Figure III). Every individual participant decreased their absolute SS magnitudes during OLS trials, compared to control trials, for the middle, later and total sections. There were no statistically significant ($P > .050$) correlations between SS and any of the 208 separate comparisons, thus, it was unnecessary to display all 208 correlation results individually in the text or visually.

Therefore, the grouped Pearson correlation results are as follows. For the trained group, during control trials, and for each phase (initial, middle, later or total sections) there were no statistically significant ($P > .050$; range, $P = .691$–$.974$) correlations (trivial–moderate effects; range $r = .034$–$.411$) between SS and any sprint characteristic measured(RS, step length, step frequency, support time, flight time, SW, mediolateral positive impulse, mediolateral negative impulse, mediolateral net impulse, propulsive impulse, braking impulse, anteroposterior net impulse and effective vertical impulse).For the trained group, during OLS trials, and for each phase there were no statistically significant ($P > .050$; range, $P = .629$–1.000) correlations (trivial–moderate effects; range $r = .000$–$.500$) between SS and any sprint characteristic measured.

For the untrained group, during control trials, and for each phase there were no statistically significant ($P > .050$; range, $P = .778$–$.995$) correlations (trivial–small effects; range $r = .006$–$.289$) between SS and any sprint characteristic measured. For the untrained group, during OLS trials, and for each phase there were no statistically significant ($P > .050$; range, $P = .780$–$.994$) correlations (trivial–small effects; range $r = .007$–$.286$) between SS and any sprint characteristic measured.

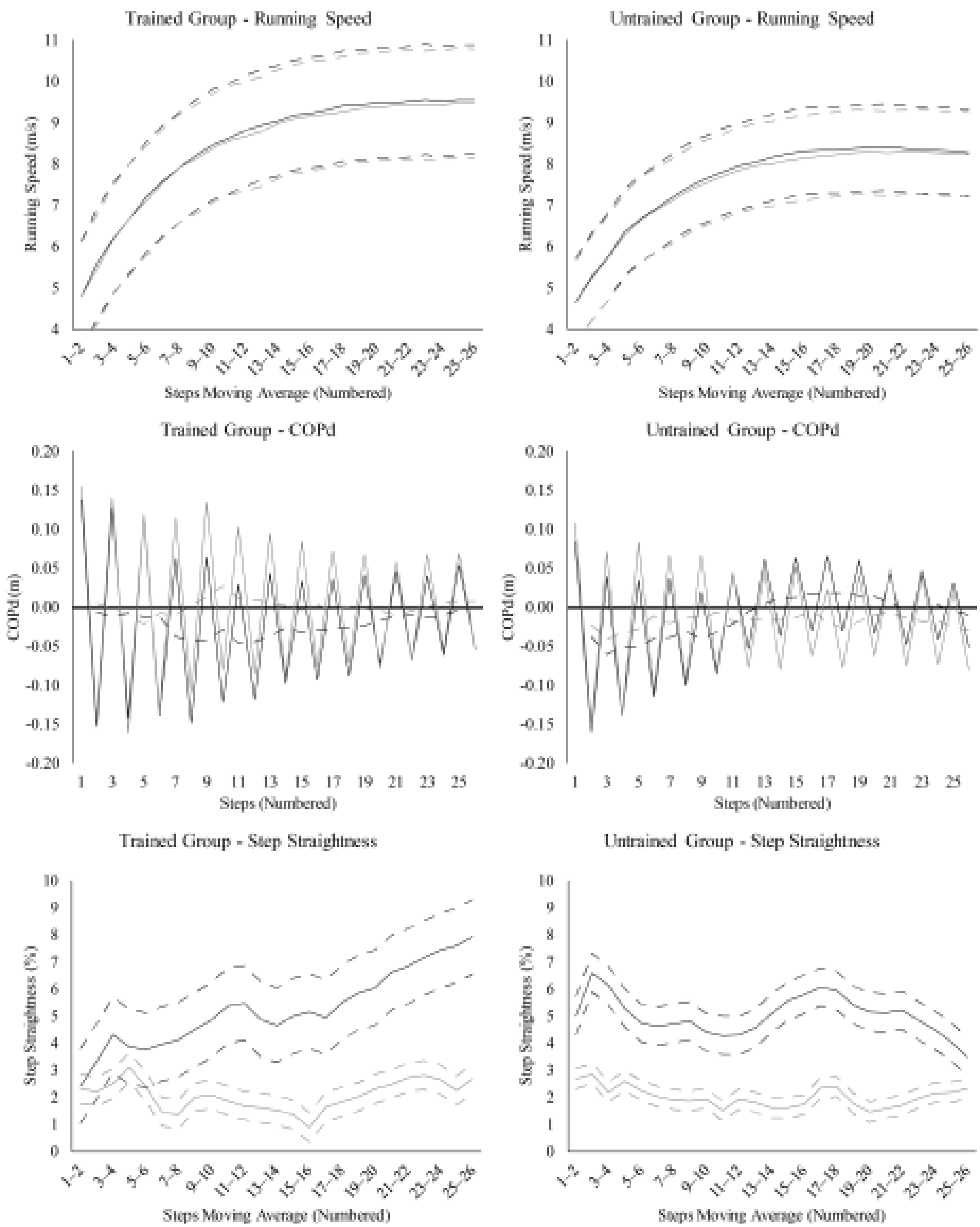

Figure I. Means (solid lines) and standard deviations (dashed lines) for the control (black) and over-line sprint trials (grey), for running speed and step straightness. The graph in the middle for both groups shows the means of step-to-step (solid lines) centre of pressure distance (COPd) and the moving average (dashed lines) for the control (black) and over-line sprint trials (grey). Group of focus and sprint characteristic labelled in figure titles.

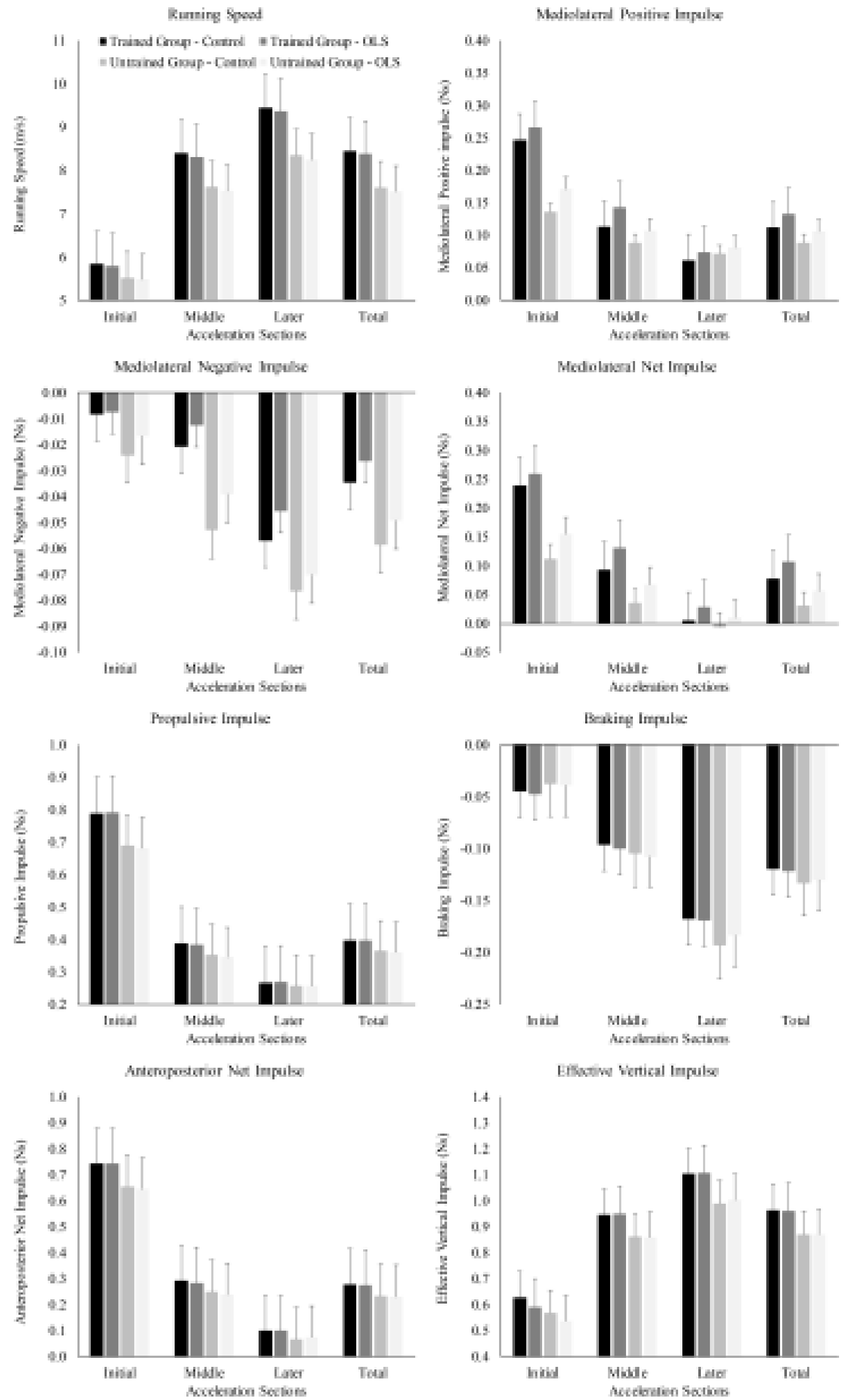

Figure II. Running speed and kinetic variables mean (bars) plus standard error (error lines) during the initial, middle, later and total acceleration phase sections, for the trained and untrained group control and over-line sprint (OLS) trials.

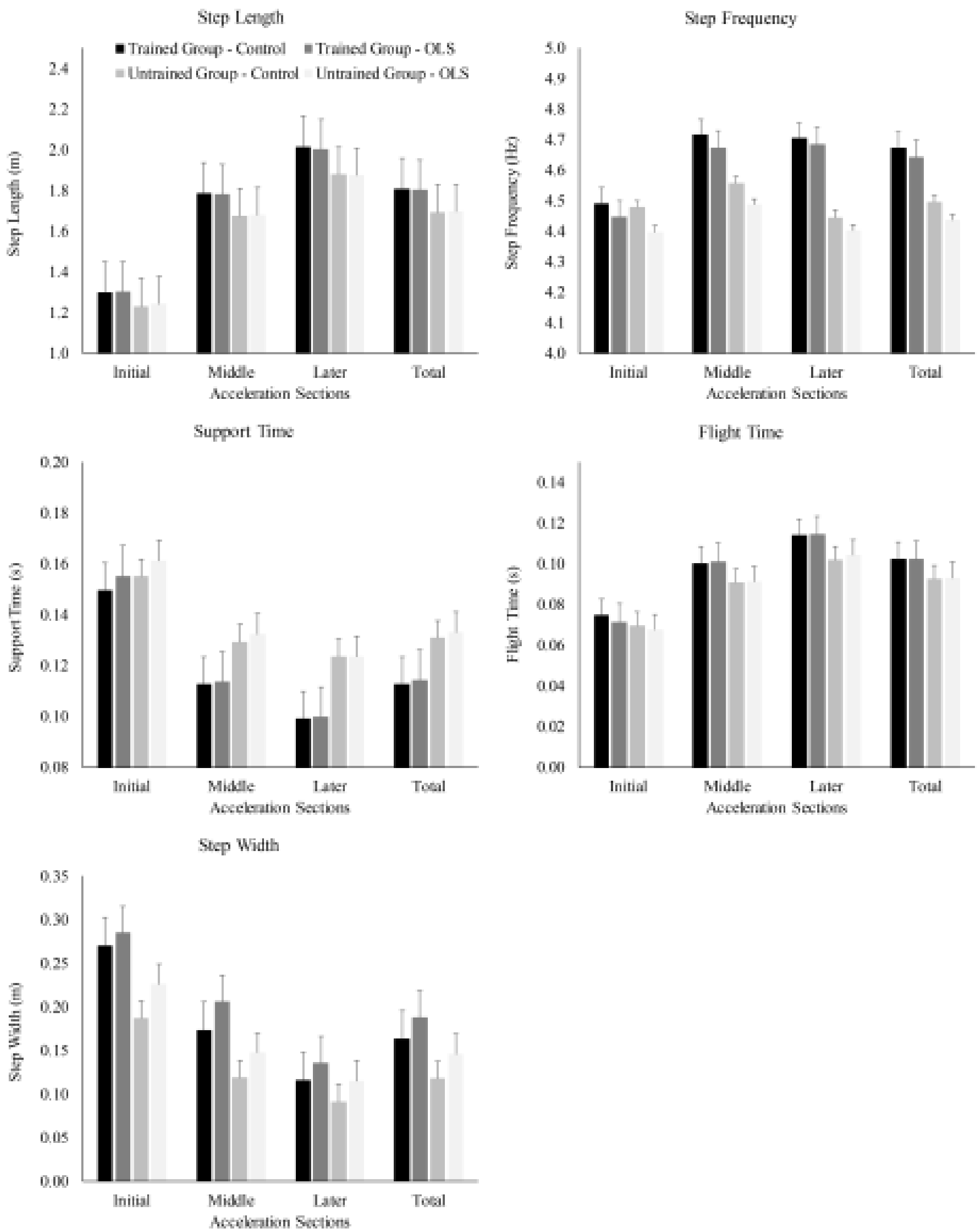

Figure III. Kinematic variables mean (bars) plus standard error (error lines) during the initial, middle, later and total acceleration phase sections, for the trained and untrained group control and over-line sprint (OLS) trials.

Discussion

The main findings demonstrated no statistically significant correlations, with only trivial–moderate effects, for any of the 208 individual correlation comparisons with SS in the trained or untrained group. These results demonstrated that SS is not a determinant of performance within a homogeneous group of trained or untrained sprinters and the hypothesis that statistically significant RS associations with SS would exist was rejected in the case of the two cohorts studied. Furthermore, no kinetic or kinematic associations with SS were found for any of the 12 sprint characteristics measured, thus, the further hypothesis that SS would be statistically significantly associated with SW was further rejected. Therefore, there may be no practical importance of SS for inclusion in training prescription or technique coaching for small changes in sprint performance.

There was an observable qualitative difference in sprint characteristics and SS magnitudes between the trained and untrained group (Figure I and Figure II and Figure III), probably due to the difference in sprint expertise. However, no statistically significant correlations were found within either cohort, suggesting that results may be translatable to other populations, such as female athletes (Ciacci et al., 2017)or adolescent athletes (Nishimura et al., 2020). Theoretically, straightness should be important for small performance changes, however, the reason for no statistically significant correlations of SS may be due to individual SS differences between participants or the small magnitude of SS change step-to-step. For example, an athlete may travel over the middle of a lane linearly or 15 cm parallel toward the left side of a lane linearly, but the sprint characteristics between these two hypothetical conditions, such as SW, may remain unchanged or non-significantly different over the period of an entire acceleration section. Although results suggest that there is no practical importance of straightness, the results may differ if focusing on the steps in which deviations from a straight linear path occurred, which may be an area for future research investigation.

The OLS intervention was included during data collection, prior to analysis, for the purpose of clarifying whether the magnitude of SS importance (correlations) changed due to an athlete focusing on running straight. Every participant demonstrated SS decreases (straighter linear sprints) during OLS, compared to control trials, for both groups middle, later and total acceleration sections. These SS magnitude decreases suggested that an OLS intervention may practically improve SS in sprint trained or untrained athletes, which may be an area for future research investigation. The OLS visual intervention is highly practical due to training programs not requiring any changes to implement, other than the focus and position of the athlete slightly shifting to over a line. If coaches wish to improve linear sprint straightness for an athlete, an OLS intervention may be used, however, despite SS improvements in this study due to OLS,a furtherstatistical comparison between OLS and control sprints was considered unnecessary for inclusion in this study due to correlation results (no practical beneficial importance of SS). Therefore, any further OLS analysis was excluded from results.

Conclusions

This research defined a new characteristic of sprinting (SS) and a new sprint training modality (OLS). This is the first known research to elucidate the importance of straightness during linear sprint running. The SS measure is the moving average of step-to-step COPd, thus, demonstrates the path that an athlete travels(body position relative to the centre of a straight running lane). In this study, the unit of SS was a percentage to control for height differences among the cohorts. Therefore, a larger SS represented increasing mediolateral distance away from the centre of the track, and a lower SS represented a straighter sprint path. Theoretically, decreasing SSimproves general sprint straightness, and this research demonstrated original insight to this new novel field by suggesting an OLS intervention may improve straightness. The potential impact of this finding is widespread for coaches and athletes, in terms of sprint training prescription and performance strategy, due to the applicability of linear sprinting in many sport competitions, training programs and recreational exercise. However, results showed that SS was not a determinant of sprint performance and the hypothesis that SS would be associated to sprint characteristics was rejected. Therefore, it was concluded that SS interventions appear unnecessary and other training modalities with stronger evidenced support for benefits to performance should be prioritised. Negative results, such as no statistically significant correlations, can be just as impactful as positive results in terms of practical implications. The practical implication of this study was clarifying that there is no need for coaches to encourage the straightness of running during linear sprinting or for athletes to concentrate on their body position in a lane relative to straightness.

Conflicts of interest: The authors declare no conflict of interests.

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References

Appelbaum, L. G., & Erickson, G. (2018). Sports vision training: A review of the state-of-the-art in digital training techniques. *International Review of Sport and Exercise Psychology*, *11*(1), 160-189.

Ciacci, S., Merni, F., Bartolomei, S., & Di Michele, R. (2017). Sprint start kinematics during competition in elite and world-class male and female sprinters. *Journal of sports sciences*, *35*(13), 1270-1278.

Clark, K. P., Ryan, L. J., & Weyand, P. G. (2017). A general relationship links gait mechanics and running ground reaction forces. *Journal of Experimental Biology*, *220*(2), 247-258.

Gleadhill, S., & Nagahara, R. (2020a). Kinetic and kinematic determinants of female sprint performance. *Journal of Sports Sciences*, 1-9.

Gleadhill, S., & Nagahara, R. (2020b). Step-to-step spatiotemporal determinants of female sprint performance during the entire acceleration phase. *ISBS Proceedings Archive*, *38*(1), 88.

Holmyard, D., Cheetham, M., Lakomy, H., & Williams, C. (1988). Effect of recovery duration on performance during multiple treadmill sprints. *Science and football*, 134-142.

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. In: LWW.

Ito, A., Ishikawa, M., Isolehto, J., & Komi, P. V. (2006). Changes in the step width, step length, and step frequency of the world's top sprinters during the 100 metres. *New Studies in Athletics*, *21*(3), 35.

Majumdar, A. S., & Robergs, R. A. (2011). The science of speed: Determinants of performance in the 100 m sprint. *International Journal of Sports Science & Coaching*, *6*(3), 479-493.

Morin, J.-B., Slawinski, J., Dorel, S., Couturier, A., Samozino, P., Brughelli, M., & Rabita, G. (2015). Acceleration capability in elite sprinters and ground impulse: push more, brake less? *Journal of biomechanics*, *48*(12), 3149-3154.

Murata, M., Takai, Y., Kanehisa, H., Fukunaga, T., & Nagahara, R. (2018). Spatiotemporal and kinetic determinants of sprint acceleration performance in soccer players. *Sports*, *6*(4), 169.

Nagahara, R., Kanehisa, H., & Fukunaga, T. (2020). Ground reaction force across the transition during sprint acceleration. *Scandinavian Journal of Medicine & Science in Sports*, *30*(3), 450-461.

Nagahara, R., Matsubayashi, T., Matsuo, A., & Zushi, K. (2014a). Kinematics of transition during human accelerated sprinting. *Biology open*, *3*(8), 689-699.

Nagahara, R., Mizutani, M., Matsuo, A., Kanehisa, H., & Fukunaga, T. (2017). Association of step width with accelerated sprinting performance and ground reaction force. *International journal of sports medicine*, *38*(07), 534-540.

Nagahara, R., Mizutani, M., Matsuo, A., Kanehisa, H., & Fukunaga, T. (2018a). Association of sprint performance with ground reaction forces during acceleration and maximal speed phases in a single sprint. *Journal of Applied Biomechanics*, *34*(2), 104-110.

Nagahara, R., Mizutani, M., Matsuo, A., Kanehisa, H., & Fukunaga, T. (2018b). Step-to-step spatiotemporal variables and ground reaction forces of intra-individual fastest sprinting in a single session. *Journal of sports sciences*, *36*(12), 1392-1401.

Nagahara, R., Naito, H., Morin, J.-B., & Zushi, K. (2014b). Association of acceleration with spatiotemporal variables in maximal sprinting. *International journal of sports medicine*, *35*(09), 755-761.

Nishimura, S., Miyazaki, A., Kinomura, Y., Kizuka, T., & Okade, Y. (2020). Identifying an effective technique to improve the sprinting performance of male high school students who have a low sprinting ability. *Journal of Physical Education and Sport*, *20*, 2021-2029.

Rabita, G., Dorel, S., Slawinski, J., Sàez-de-Villarreal, E., Couturier, A., Samozino, P., & Morin, J. B. (2015). Sprint mechanics in world-class athletes: a new insight into the limits of human locomotion. *Scandinavian journal of medicine & science in sports*, *25*(5), 583-594.

Sandamas, P., Gutierrez-Farewik, E. M., & Arndt, A. (2019). The effect of a reduced first step width on starting block and first stance power and impulses during an athletic sprint start. *Journal of sports sciences*, *37*(9), 1046-1054.

Sandamas, P., Gutierrez-Farewik, E. M., & Arndt, A. (2020). The relationships between pelvic range of motion, step width and performance during an athletic sprint start. *Journal of Sports Sciences*, *38*(19), 2200-2207.

Slawinski, J., Termoz, N., Rabita, G., Guilhem, G., Dorel, S., Morin, J. B., & Samozino, P. (2017). How 100-m event analyses improve our understanding of world-class men's and women's sprint performance. *Scandinavian journal of medicine & science in sports*, *27*(1), 45-54.

Smith, T. B., & Hopkins, W. G. (2012). Measures of rowing performance. *Sports Medicine*, *42*(4), 343-358.

Weyand, P. G., Sternlight, D. B., Bellizzi, M. J., & Wright, S. (2000). Faster top running speeds are achieved with greater ground forces not more rapid leg movements. *Journal of applied physiology*, *89*(5), 1991-1999.

Wiemann, K., & Tidow, G. (1995). Relative activity of hip and knee extensors in sprinting-implications for training. *New studies in athletics*, *10*, 29-29.