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Acute effects of different loading protocols upon performance and kinematics of 180 degrees change of direction

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ABSTRACT

This study examined the acute effects of different loading protocols on 180° change of direction (COD) performance in eleven male handball players. Participants performed a 10-0-5 COD test under seven conditions: without an external load, and with 3, 6, and 9 kg loads applied under two modes—assisted into the COD and resisted out of it and resisted into the COD and assisted out of it. While total COD time was not affected (p = 0.098; η^2 = 0.16), significant phase effects were observed (p < 0.001; η^2 ≥ 0.55). Loading protocols significantly influenced velocity, acceleration, and their distances from COD (p < 0.001; η^2 ≥ 0.37). Significant phase effects were observed for all step kinematic variables (p ≤ 0.037; η^2 ≥ 0.67), except contact time, and significant interaction (phase*condition) effects for all variables (p ≤ 0.004; η^2 ≥ 0.08), except for step frequency. Assisted-resisted protocols increased deceleration demands through higher COD entry velocities, displaying fewer but longer steps in the acceleration phase and greater steps taken during the deceleration phase. Resisted-assisted protocols decreased deceleration demands due to lower COD entry velocities, displaying shorter, but more steps taken in the acceleration phase, and fewer steps taken in the deceleration phase. These findings suggest that assisted-resisted and resisted-assisted loading protocols can be used to selectively overload specific phases of COD performance.

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KEYWORDS
Assisted sprinting; resisted sprints; COD; Dynaspeed; step kinematics

Introduction

The ability to swiftly decelerate, execute abrupt turns (>60°) and rapidly re-accelerate into a different direction, known as change of direction (COD) speed performance (Comfort et al., 2018), is crucial in numerous field- and court-based sports. This importance is highlighted by the frequent execution of COD manoeuvres observed in sports such as handball (Karcher & Buchheit, 2014) and basketball (Conte et al., 2015), where approximately 20–30% of high-intensity actions consist of COD manoeuvres. In individual sports such as tennis, athletes have been observed to execute an average of 250

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CODs per best-of-three set match (Giles et al., 2024). COD speed performance has also been shown to discriminate between athletes of differing performance levels (Keiner et al., 2021; Till et al., 2017; Volk et al., 2023) and is often used for talent identification (Höner et al., 2021; Till et al., 2017; Vuong et al., 2022) and performance monitoring purposes (Ebben & Blackard, 2001; Ebben et al., 2004; T. W. Jones et al., 2016). Given the significance of COD speed performance in many field- and court-based sports, it is necessary to identify and evaluate potential training strategies for improving COD speed performance in athletes.

COD speed performance is thought to be reliant on a multitude of kinetic and kinematic qualities (Sheppard & Young, 2006). Specifically, previous research has found that performance in COD speed tasks are positively associated with greater peak and approach velocities (Dos'santos et al., 2020; Hader et al., 2015; P. A. Jones et al., 2017; Nygaard Falch et al., 2020) shorter ground contact times (GCTs) during the penultimate and final step (Dos'santos et al., 2017, 2020, 2022; Maloney et al., 2017; Marshall et al., 2014) greater horizontal braking forces during the penultimate and final step (Dos'santos et al., 2017, 2020; Graham-Smith et al.,) greater horizontal propulsive forces (Dos'santos et al., 2017, 2020) and smaller vertical propulsive forces during the penultimate and final steps (Dos'santos et al., 2017). Regarding joint-specific kinetics and kinematics, research indicates that achieving shorter completion times in COD speed tasks is underpinned by specific biomechanical factors. These include a narrower lateral pelvic tilt range during the final step (Marshall et al., 2014), increased thorax lateral rotation angle towards the new direction (Marshall et al., 2014), heightened hip frontal plane power generation (Havens & Sigward, 2015), amplified maximum ankle power and ankle plantar flexion moment during the final step (Marshall et al., 2014). During the turn a greater trunk forward angular displacement between final foot contact and maximum trunk inclination (Sasaki et al., 2011). Furthermore, enhanced peak hip flexion, knee flexion, ankle dorsiflexion angles and increased trunk displacement during the penultimate step (Dos'santos et al., 2020), were observed. At initial contact of the penultimate and final steps, augmented forward trunk inclination angles, and heightened medial trunk flexion away from the plant leg at the initial contact of the final step (Dos'santos et al., 2020) were detected. Finally, Dos' Santos, Thomas, Comfort, Jones (Dos'santos et al., 2022), have also observed improvements in COD speed performance across a training intervention to be associated with increases in peak knee flexion moments, horizontal braking forces, ankle dorsi-flexion ranges of motion, decreases in penultimate step GCTs, and increased in peak velocity. Thus, depending on the demands of the sport and an athlete's strengths and weaknesses, training interventions aimed at improving COD speed performance should aim to overload one or more of the aforementioned qualities or their underlying determinants.

A number of various training approaches have been investigated for their effects on COD speed performance, namely plyometric training, strength training, linear sprint training, as well as specific COD training (Nygaard Falch et al., 2019). While all of these training approaches have their unique benefits, it is imperative that a holistic training programme includes strategies that overload key performance qualities through both specific (i.e., movement patterns closely imitating the sport-specific task) and non-specific (i.e., movement patterns further removed from the sport-specific task) exercises and drills. This in order to minimise the development of physical weaknesses and imbalances. Though several studies have investigated the effects of specific COD training on COD speed performance over a training mesocycle, the effects of acutely loading the specific COD movement that formed these training interventions are relatively unknown (Nygaard Falch et al., 2019).

In line with the concept of training specificity, adding horizontal resistance and assistance during COD manoeuvres would provide directed overload for such tasks. Training with horizontal resistance and/or assistance is commonly seen in sprint training (Haugen et al., 2019), where these methods are used to overload various kinematic parameters thought to impact overall linear speed performance (Cecilia-Gallego et al., 2022; Kawamori et al., 2014; van den Tillaar & Mirkov, 2021; Zisi et al., 2022). For example, adding resistance when sprinting increases GCT and decreases step length (Alcaraz et al., 2008; Lockie et al., 2003; Pareja-Blanco et al., 2022) while adding assistance when sprinting decreases GCT and increases step length (Clark et al., 2021; van den Tillaar & Gamble, 2018; van den Tillaar & Mirkov, 2021). To date, only a single study has investigated the application of horizontal resistance during a COD task (Eriksrud et al., 2022). Eriksrud, Ahlbeck, Harper, Gløersen (Eriksrud et al., 2022) determined that a horizontal pulley device can be used as a valid method for assessing entry and exit velocities while performing a modified 505 test while being assisted into and resisted out of the COD with 3, 6, and 9 kg loads (r = 0.53–1.00; CV = 0.3–7.7%). However, since the study only used one type of loading protocol (i.e., assisted into resisted) and did not directly compare the effects of the loading conditions on COD performance, it is unknown how the magnitude and application of load influence phase-specific COD performance. Given these findings, more research into the effects of horizontal resistance and assistance during COD tasks is warranted.

There are two ways in which horizontal resistance and assistance can be provided during 180° COD tasks: (1) assistance from start to turn and resistance from turn to finish; and (2) resistance from start to turn and assistance from turn to finish. The two different types of loading may uniquely overload different phases of a COD. However, whether this holds true has yet to be investigated. Therefore, the aim of this study was to compare the phase-specific performance characteristics and step kinematics of 3, 6, and 9 kg loads provided from both directions (i.e., assisted into resisted COD and resisted into assisted COD) with those of an unresisted 180° COD task. It was hypothesised that velocity, acceleration and step length would increase in the phases when being assisted and decrease in the phases when being resisted. Moreover, it was also hypothesised that being assisted into the turn would increase the distance required to decelerate while being resisted into the turn would lead to a shorter distance required to decelerate and longer ground contact times prior to performing the turn. The knowledge gained from the present study could help coaches and athletes in designing different loading protocols for training CODs.

Materials and methods

Using a randomised counterbalanced design each participant completed the 10-0-5 COD test with the following conditions: unresisted, assisted into resisted COD with 3, 6, and 9 kg, and resisted into assisted COD with 3, 6, and 9 kg. The 10-0-5 COD test with these loads were chosen as Eriksrud, Ahlbeck, Harper, Gløersen (Eriksrud et al., 2022) determined that this test with using a horizontal pulley device was a valid and reliable test. This made it also possible to compare some results from the present study with this previous one. Two maximal-effort attempts were performed for each condition and the 180° turns were performed with participants' preferred turning legs only. Hence, each participant performed a total of 14 COD trials, each interspersed by a 1–2 minute passive rest period. Trial order for participants was randomised to counteract any potential order effects.

Participants

Eleven healthy, male handball players (age: 25.2 ± 7.5 yrs., height: 1.76 ± 0.07 m, body mass: 75.0 ± 14.6 kg) volunteered to participate in the present study. Only eleven players were used as a previous similar study by Eriksrud, Ahlbeck, Harper, Gløersen (Eriksrud et al., 2022) indicated that the sample size was enough for these type of analysis as it was a within-subject design. All participants competed at a regional level in the senior age group, and none had prior experience with performing assisted and resisted CODs. Written informed consent was obtained from all participants. The study was approved by the Norwegian Agency for Shared Services in Education and Research (project nr. 902786) and complied with the current ethical standards in sports and exercise science research.

Procedures

All participants performed one familiarisation session in which also their preferred turning leg was determined followed by one experimental session seven days later. Prior to the commencement of each session, participants performed a 10-minute standardised warm-up that included 8 × 40 m runs at progressive intensity and lower limb dynamic stretches. The first warm-up sprint was performed at a self-regulated intensity of approximately 60%. With each successive 40 m sprint, players increased running intensity by approximately 5% until it reached 95% of the self-estimated maximum running speed. Lower limb dynamic stretches were performed in-between each sprint.

After the warm-up, participants performed the 10-0-5 COD test, which involves a 10 m sprint, followed by a 180° turn, followed by a 5 m sprint back into the

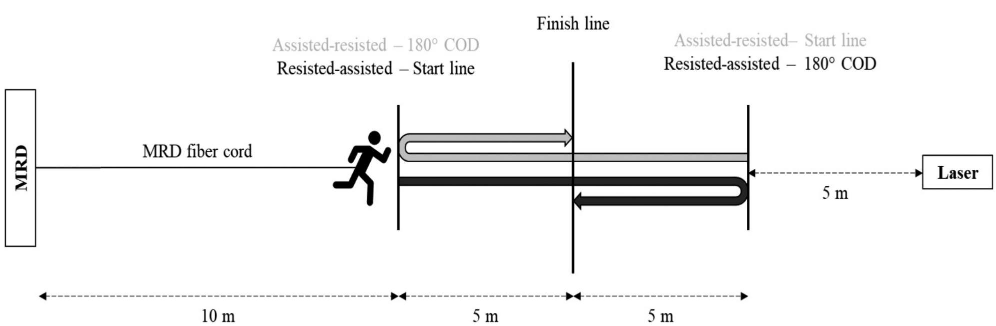

Figure 1. Visual representation of test set-up.

opposite direction (Figure 1). Load for all, except the unresisted condition, was provided by a motorised resistance device (MRD) (DynaSpeed, Ergotest Technology AS, Langesund, Norway), which was placed in line with the runway and approximately 10 m away from the start or turning position (depending on condition) to assure that the player has enough distance to stop after the COD, especially in the resisted-assisted conditions. The fibre cord from the MRD was attached to the participant's waist using a carabiner onto a pulley, which in turn was attached to a belt with two carabiners. Assisted-resisted conditions were performed with initial acceleration being towards the MRD and resisted-assisted conditions were performed with the initial acceleration being away from the MRD. The unresisted condition was performed without any of the aforementioned MRD equipment. Each COD trial was performed from a standing split stance start, with the lead foot behind a line taped on the floor, and with a self-initiated start.

Velocity measurements were recorded continuously during each attempt using a laser gun (Ergotest Technology AS, Langesund, Norway), sampling at 2.56 kHz. The laser gun was positioned on the opposite of the COD test, relative to the MRD, and 5 m away from the start or turning position (depending on condition). Step kinematics were measured using two wireless inertial measurement units (IMUs) (Ergotest Technology AS, Langesund, Norway) with a sampling rate of 200 hz. These were attached to the top of the shoelaces using tape. All recordings of the laser gun and the IMUs were automatically synchronised with the Musclelab software version 10.232.111.5329 (Ergotest Technology AS, Langesund, Norway).

Data processing

Data obtained from the laser device was used to analyse outcome variables pertaining to time, distance, and velocity. For this purpose, the raw data of each participant's fastest trial for each of the seven conditions was exported and subsequently imported to R Studio (version 4.3.1) for further analysis. Data processing included the following steps: (i) conversion of timestamp unit from milliseconds to seconds; (ii) manual removal of impossible distance data points, which were detected using the graph mode of the Musclelab Software; (iii) removal of impossible velocity data points, defined as velocities above and below 12.5 and −12.5 m/s, respectively; (iv) spline interpolation of all deleted data points; and, (iv) application of a fourth-order, zero-lag, low-pass Butterworth filter with a cut-off frequency of 1 hz. Following this, trials were exported to Microsoft Excel for further processing and analyses.

In Microsoft Excel, trials were manually processed by removing all data recorded before the start of the trial and following the end of the trial. The start of a trial was defined as when the velocity surpasses 0.2 m/s measured with the laser using the graph editor of the Musclelab Software. The end of a trial was defined as the first data point following the turn where distance equals peak distance subtracted by 5 m.

Once processing was complete, the following data points were used to define the COD phases: (i) acceleration = start until peak velocity prior to the turn; (ii) deceleration = peak velocity prior to the turn until the instant where velocity equals 0; and (iii) re-acceleration = instant where velocity equals 0 until end of test. Thereafter, the average acceleration for each phase was calculated using the following equation:

$$acceleration\left(m/s^2\right) = \frac{v_f - v_i}{t_f - t_i}$$

where v is the velocity, t is the time, f is the velocity or time at the end of a phase, and i is the velocity or time at the start of the phase.

Based on the processed data, the outcome variables of interest included total test time, time spent in each phase, distance at which peak velocity before COD is reached, peak velocity in the acceleration and re-acceleration phases, and average acceleration in the acceleration, deceleration, and re-acceleration phases.

IMU data from the two sensors on the shoes was used to analyse outcome variables relating to step kinematics. To identify step contact and flight times, the pattern of angular velocity of ankle plantar flexion and extension together with acceleration pattern (sudden increases) was analysed visually using the graph editor of the Musclelab Software, using the same methods as described previously by van den Tillaar, Nagahara, Gleadhill, Jiménez-Reyes (van den Tillaar et al., 2021). Every step (contact and flight time) was analysed during the whole COD. Average contact and flight times for each of the three phases were calculated. Furthermore, the average number of steps was calculated. Percentage of the step (touch down = 0% and end flight phase = 100%) was calculated at the peak velocity and the 5 m mark to be as accurate as possible for calculating the number of steps per phase. The average step length was calculated by the distance covered in each phase divided with the number of steps in this phase. Lastly, step frequency was calculated as follows:

$$step\ frequency(n/s) = \frac{n_{steps}}{t}$$

where n_{steps} is the number of steps taken during a phase and t is the total duration of the same phase.

Statistical analysis

To assess the acute effects of the different loading protocols upon the performance and kinematics of the 180° COD, a one-way analysis of variance (ANOVA) with repeated measures was performed. A two-way ANOVA with repeated measures (phases and loading protocol) was performed on the average step kinematics of the three phases during the different loading protocols together with a one-way ANOVA per phase to identify the effect of loading protocol per phase. Post hoc comparisons were performed between the unresisted condition with the other loaded protocols with a Holm—Bonferroni correction. The assumption of sphericity was controlled by using Mauchly's test of sphericity. If the assumption of sphericity was violated, the Greenhouse—Geisser adjusted p-value was reported. The level of significance was set at $p < 0.05$. Data are reported as means ± standard deviations. Effect size was evaluated as eta squared (η (Karcher & Buchheit, 2014), whereby 0.14 > η (Karcher & Buchheit, 2014) was defined as a large effect, 0.06 to 0.14 η (Karcher & Buchheit, 2014) a medium effect, and 0.01 to

0.06 η (Karcher & Buchheit, 2014) a small effect (Cohen, 1988). The statistical analysis was conducted in JASP v 0.17.3 (University of Amsterdam, Amsterdam, Netherlands).

Results

The different loading protocols had no significant effect upon the total COD time ($F = 1.89$; $p = 0.098$; η (Karcher & Buchheit, 2014) = 0.16). However, when analysing per phase, significant effects were found for the time of each of the different phases ($F \geq 12.32$; $p < 0.001$; η (Karcher & Buchheit, 2014) ≥ 0.55). Still, post hoc comparison revealed that the total time in the resisted-assisted protocols with 3 and 9 kg were significantly longer than with the unresisted condition ($p \leq 0.046$). Furthermore, the acceleration time was longer when performing the resisted-assisted protocols and shorter when performing assisted-resisted condition with 6 kg compared with the unresisted condition. Deceleration time only increased significantly from unresisted to 3 kg assisted-resisted condition, while 5 m time after the COD was significantly shorter between the resisted-assisted 9 kg condition with the unresisted condition and increased significantly with each assisted-resisted load (Figure 2).

When evaluating the distance of peak velocity from COD, the velocities and accelerations at the different phases were all affected by the loading protocols ($F \geq 5.77$; $p < 0.001$; η (Karcher & Buchheit, 2014) ≥ 0.37). Post hoc comparison showed that the distance at which peak velocity was reached before COD decreased when performing the resisted-assisted protocols and increased when performing the assisted-resisted protocols compared with the unresisted condition (Figure 3).

In addition, the peak velocity decreased significantly when performing the resisted-assisted condition with 9 kg compared with 3 kg and this again with the unresisted condition, while it only increased significantly from the unresisted to the 3 kg assisted-resisted condition. Re-acceleration phase showed the opposite, with lower peak velocities at 3 kg and again at 9 kg assisted-resisted conditions, and significantly higher peak velocity after 5 m with all resisted-assisted conditions compared with the unresisted condition (Figure 4).

About acceleration, significantly lower acceleration with 9 kg resisted-assisted condition compared with 3 kg and again lower than the unresisted condition, while mean

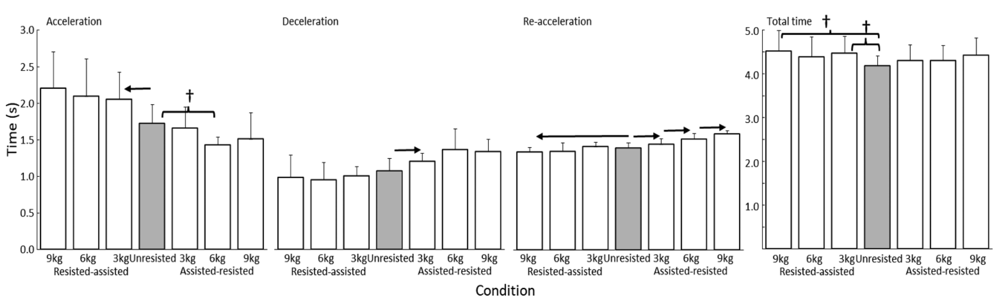

Figure 2. Mean (±SD) times of different events averaged per condition. → and ← indicate a significant difference between these two conditions and all away from the arrow on a $p < 0.05$ level. †indicates a significant difference between these two conditions on a $p < 0.05$ level.

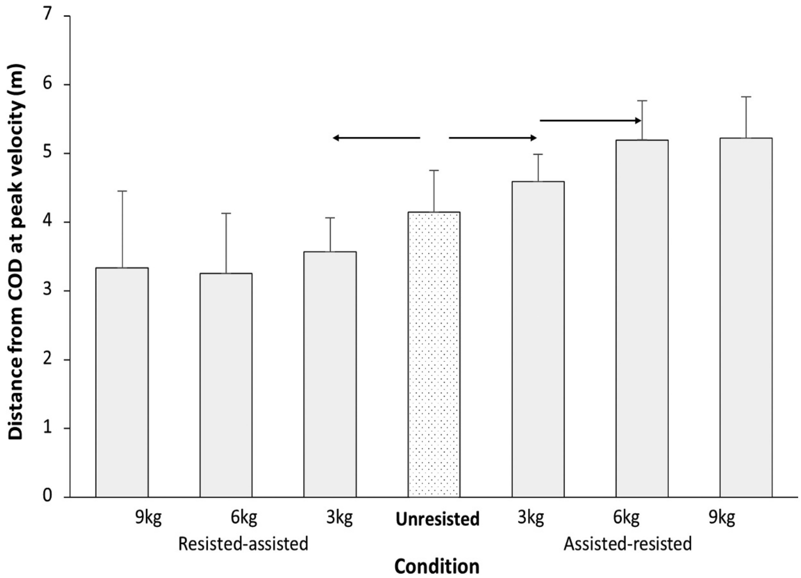

Figure 3. Mean (±SD) distance at peak velocity averaged per condition. → and ← indicate a significant difference between these two conditions and all away from the arrow on a $p < 0.05$ level.

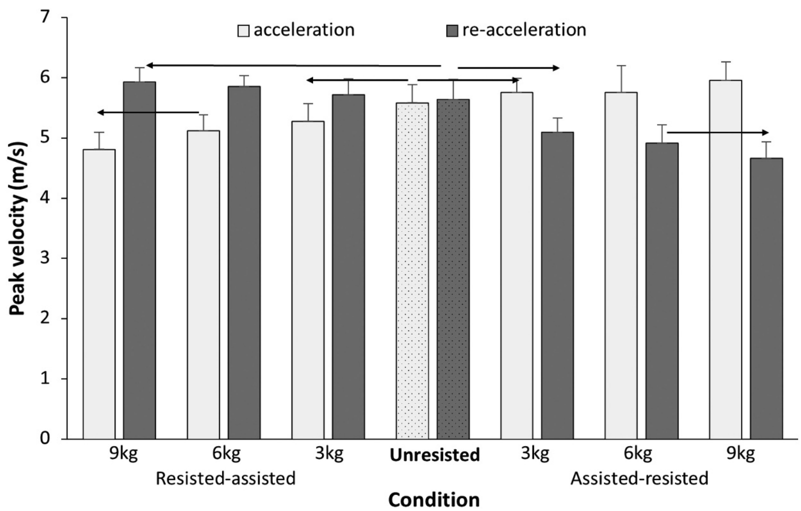

Figure 4. Mean (±SD) peak velocity acceleration and re-acceleration phases averaged per condition. → and ← indicate a significant difference between these two conditions and all away from the arrow on a $p < 0.05$ level.

acceleration increased between the 3 to 6 kg resisted-assisted conditions. Mean deceleration only decreased significantly between the unresisted to the 6 kg assisted-resisted condition (Figure 5). In addition, mean re-acceleration was significantly higher when performing the resisted-assisted 9 kg with the unresisted condition and decreased significantly with each load of the assisted-resisted condition compared with the unresisted condition (Figure 5).

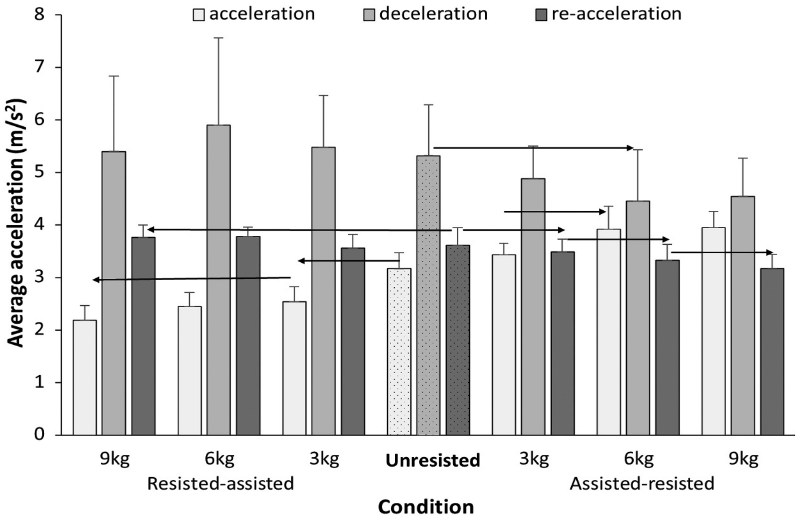

Figure 5. Mean (±SD) acceleration of different phases averaged per condition. → and ← indicate a significant difference between these two conditions and all away from the arrow on a $p < 0.05$ level.

When analysing the step kinematics for the different phases, a significant effect of phase was found for all step kinematics ($F \geq 6.02$; $p \leq 0.037$; η (Karcher & Buchheit, 2014) ≥ 0.67), except for contact time ($F = 0.88$; $p = 0.46$; η (Karcher & Buchheit, 2014) = 0.04). No significant effect of condition ($F \leq 1.10$; $p \geq 0.395$; η (Karcher & Buchheit, 2014) ≤ 0.01), while significant interaction (phase*condition) effects were found for all step kinematics ($F \geq 3.16$; $p \leq 0.004$; η (Karcher & Buchheit, 2014) ≥ 0.08), except for step frequency ($F = 0.74$; $p = 0.7$; η (Karcher & Buchheit, 2014) < 0.01).

Figure 6 provides the post hoc comparison, revealing that, regardless of loading condition, step length was shorter, the flight time was lower, step frequency was higher, and step number was greater in the deceleration phase compared to the other two phases ($p < 0.05$). In all assisted-resisted conditions, step length was longer, flight time was greater, step frequency was lower, and the number of steps was greater in the acceleration phase compared to the re-acceleration phase ($p < 0.05$). Alternatively, in the resisted-assisted loading condition, step length was shorter at the 9 kg load, and the number of steps was greater in the acceleration phase compared to the re-acceleration phase for all loads ($p < 0.05$).

Meanwhile, compared to the unloaded condition, assisted-resisted loading resulted in greater step lengths and fewer number of steps during the acceleration phase, while simultaneously decreasing step length, lowering flight time, and increasing the number of steps during the reacceleration phase ($p < 0.05$). Resisted-assisted loading was found to decrease step length and increase step number during the acceleration phase, increase the contact time but decrease step number during the deceleration phase, and increase step length and flight time, and decrease contact time and number of steps during the reacceleration phase when compared to the unloaded condition ($p < 0.05$).

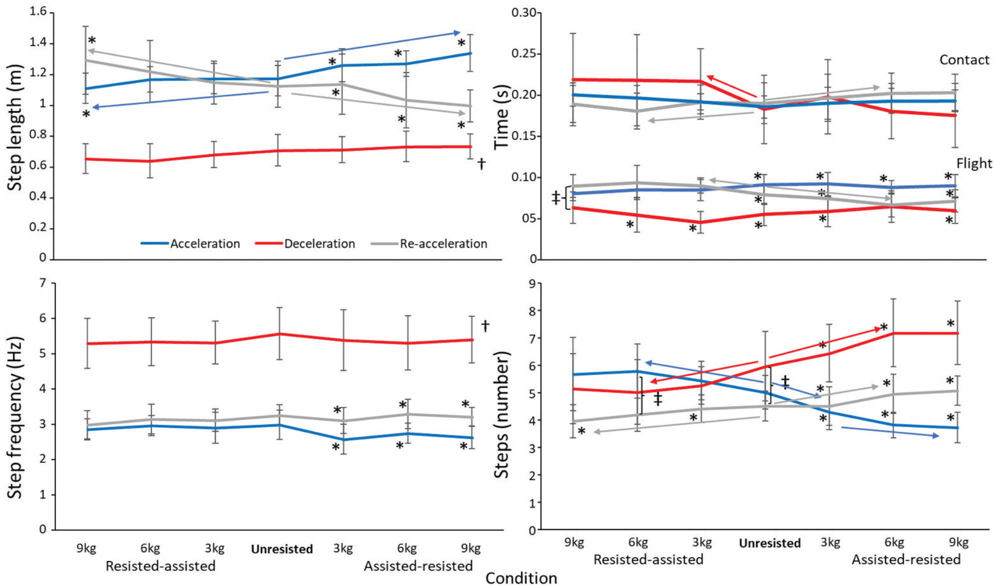

Figure 6. Average step length, frequency, contact and flight time for each phase per condition. * indicates a significant difference with all other phases for this condition on a $p < 0.05$ level † indicates a significant difference with all other phases for each condition on a $p < 0.05$ level ‡ indicates a significant difference between these two phases for this condition on a $p < 0.05$ level → and ← indicate a significant difference between these two conditions and all away from the arrow on a $p <$ 0.05 level.

Discussion and implications

The aim of the study was to investigate the effect of different loading protocols upon phase-specific performance and step kinematics of a 180° COD task. The main findings were that total time was not affected, while times of different phases, the distance of peak velocity before COD, velocities and accelerations of the different phases were uniquely affected by the different loading protocols. Moreover, while both types of loading resulted in distinctly different alterations to step kinematics, being assisted into a COD and resisted out of it resulted in the greatest differences in average step kinematics between the three phases. These findings provide novel insights into the utility of different loading protocols for overloading phase-specific COD performance.

Even though total COD time was not significantly affected by the different loading protocols, post hoc comparison clearly showed that the resisted-assisted loadings with 3 and 9 kg caused longer total COD times (Figure 2) with a large effect size (η (Karcher & Buchheit, 2014)≥0.14). While being assisted out of the COD increased reacceleration and peak velocity after the COD, this was not sufficient to compensate for the loss of time (Figure 2) due to lower initial acceleration prior to the COD (Figure 5) because of the shorter distance of the re-acceleration phase compared to the initial acceleration phase (5 vs. 10 m, respectively). Given that the average step length between the 9 kg assisted-resisted load during the initial acceleration phase is similar to the that in the resisted-assisted load at re-acceleration phase (Figure 6), it is possible that being assisted over a 10 m re-acceleration phase may off-set the time-loss resulting from the resistance into the directional change. While no other research has applied horizontal resistance into a 180° COD task, Ryan, Uthoff, McKenzie, Cronin (Ryan et al., 2024) observed that applying 1% body mass to either the forearm or shank significantly increased the time in the initial acceleration phase of a 5-0-5 COD test, and led to moderate reductions in peak acceleration in professional netball athletes. This suggests that both gravitational and horizontal loading preferentially overload acceleration into a 180° COD task.

Entry velocity is considered key influencing factor for deceleration and COD ability (Dos'Santos et al., 2018; Philipp et al., 2023). In the current study, it was found that being resisted into the COD (i.e., resisted-assisted) was found to reduce the entry velocity and enable deceleration to occur closer to the COD line. Similar findings have been reported by Philipp, Johnson, Cabarkapa, Fry (Philipp et al., 2024), who observed that wearing 2–4% body mass of wearable resistance on the lower limbs leads to lower average entry velocities and shorter deceleration distances during a 5-0-5 COD. Alternatively, the deceleration phase starts further away from the COD movement when increasing the load in the assisted-resisted condition (Figure 3). This is likely due to the finding that participants reached a higher peak velocity before the COD (Figure 4) caused by a higher acceleration (Figure 5) due to the assisted pulling force in this condition. The resulting force supplied by the assistance into the directional change required the participants to start their deceleration earlier. This is in line with Falch, Rædergård, van den Tillaar (Falch et al., 2020), who found that with a longer approach (20 vs 4 m) that results from higher entry velocity, participants start to decelerate earlier to compensate for the greater deceleration demands. This earlier deceleration also causes a significantly lower average deceleration with 6 and 9 kg assisted-resisted loads compared to the other conditions (Figure 5). Together, these findings indicate that athletes self-organise their deceleration strategy to account for the changes in horizontal momentum as a result of greater gravitational load, higher entry velocities, or being assisted into a COD with increasing load. Increasing horizontal momentum prior to a COD provides an eccentrically-biased stimulus that targets COD ability, aligning with the concept of 'training the brakes' as suggested by Fernandes, Bishop, Turner, Chavda, Maloney (Fernandes et al., 2021).

Even though the present study did not measure the COD step directly, Falch, Rædergård, van den Tillaar (Falch et al., 2020) found that COD step kinematics did not differ between the 4 m and 20 m approach. This suggests that the plant step during the directional change is similar despite the type of load applied or entry velocity on approach; meaning that most acute kinematic adaptations to COD performance occur prior to or after the directional change. This phenomenon is observed in the present study as participants had to take more steps in the deceleration phase when they were pulled with more load and they took fewer steps when being resisted in the deceleration phase with loads up to 6 kg, while step length and frequency were not affected (Figure 6).

When analysing step kinematics in the different phases between the loading conditions it also shows that the loading conditions had the greatest effect upon the acceleration and re-acceleration phases (Figure 6). Assistance resulted in increased step lengths, while resistance decreased step lengths. These findings support our hypothesis and are in accordance with earlier studies on assisted and resisted sprinting (Alcaraz et al., 2008; Clark et al., 2021; Lockie et al., 2003; Pareja-Blanco et al., 2022; van den Tillaar & Gamble, 2018; van den Tillaar & Mirkov, 2021). Step frequency was not affected much in the acceleration and re-acceleration phases, which was probably caused by the combination of adaptations of the shorter flight time and longer contact times when accelerating with resistance and the opposite when accelerating with assistance and the number of steps that decrease and increase in these phases (Figure 6). While there are no other horizontally assisted or resisted COD studies to directly compare to, these adaptations are in accordance with earlier studies in resisted and assisted sprinting (Clark et al., 2021; Lockie et al., 2003; van den Tillaar & Gamble, 2018; van den Tillaar & Mirkov, 2021).

This study is not without limitations. As we did not measure kinetics with force plates we could not confirm the statement of similar forces and power in the COD movement. Therefore, in future studies force plates should be included to offer more insight about the forces that occur during the different phases and loading conditions. Force plate technology could also give more insight into the braking and propulsive forces during the last steps under these conditions to investigate if more eccentric forces apply under different conditions. Due to the limited sample size, it was not possible to investigate the differences in step kinematics and movement strategies in the different phases between the faster and slower participants and the effect of the different loading protocols upon these faster and slower participants. It is important to note that this study used absolute loading strategies instead of relative ones. This is advantageous for practical scenarios but does not account for differences in individual's mass or strength, which may lead to athlete's experiencing relatively different changes in horizontal momentum. Finally, joint kinematics and step kinetics were not captured in the current study, leaving a gap in our understanding pertaining to the influence of the loading modalities on technique and force application. Therefore, future studies should adapt their methods to account for the gaps in our understanding on this topic, along with the inclusion of training over a longer period to investigate how these different loading strategies can affect COD performance.

Conclusion

In conclusion, this study provides novel insights into the effects of different loading protocols on phase-specific performance and step kinematics during a 180° change of direction (COD) task. While the total COD time remained largely unaffected, the various loading protocols uniquely influenced phase-specific times, velocities, accelerations, and step kinematics. Notably, adding assistance prior to the directional change increases the braking demands due to greater initial acceleration leading to higher velocities to decelerate from. Alternatively, adding resistance prior to the directional change increases the propulsive demands, leading to decreased braking demands because athletes achieve lower initial acceleration and initiate the deceleration from lower entry velocities. Moreover, the assisted-resisted protocol demonstrated the most pronounced differences in average step kinematics across the three phases. These findings underscore the potential utility of tailored loading protocols for overloading phase-specific COD performance. Future research should incorporate force plate technology to further elucidate the kinetic demands of these loading strategies and investigate their long-term training effects on athletes with varying COD proficiency levels.

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