APPLICATION OF QUALITATIVE MOVEMENT DIAGNOSIS ON SPRINT START

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The purpose of this study was to examine the effect of applying Qualitative Movement Diagnosis (QMD) on sprint start performance. Twelve NCAA II sprinters volunteered for this cross-sectional study. The steps of applying QMD in sprint start performance were introduced. Subjects were asked to perform three pre-intervention trials of block starts in their preferred setting. The block setting and joint kinematics at knee and hip from both sides of body were evaluated. The feedback was provided for the three post-intervention trials. A moderate effect of significant improvement of exist velocity ($p = 0.04$) was observed as well as lead leg hip angle ($p = 0.004$), rear leg knee angle ($p = 0.001$), and block spacing ($p < 0.001$). QMD, which consists of preparation, observation, evaluation/diagnosis, and intervention, can be used to effectively change and improve sprint start performance.

KEYWORDS: angular position, block start, coaching, exit velocity.

INTRODUCTION: Short-distance track and field sprints are renowned for their popularity and excitement worldwide. In these highly competitive sports, the distinction between victory and defeat is often measured in fractions of seconds. For instance, in the recent 2020 Tokyo Olympics and 2016 Rio Olympics' 100m men's final, the time difference between first and third place was only 0.09 seconds and 0.1 seconds, respectively. Studies have diligently sought to identify the optimal body configuration on the starting block that influences sprint start performance, aiming to uncover the relationship between the start and acceleration phases for elite athletes to improve their records (e.g., Harland & Steele, 1997; Čoh et al., 2006). Sprint start performance significantly correlates with overall 100m time, given that world-class sprinters achieve approximately one-third of their maximum speed in the first 5% of the time upon leaving the block (Bezodis et al., 2015).

While crucial factors influencing sprint start performance have been identified, the application of evidence-based coaching strategies remains limited. In sports, biomechanical principles form a crucial foundation for qualitative and quantitative analyses, providing interventions to enhance athletes' performance and skills. To offer practical interventions for coaches and athletes with restricted access to applied biomechanical knowledge, qualitative analysis should complement quantitative analysis (Knudson, 2007; Lees, 1999). Current findings emphasize the significance of multiple kinetic variables such as rate of force development and power in relation to block performance (Bezodis et al., 2015; Terczyński, 2014). However, the practical use of these variables for field assessment or training is limited. Conversely, angular kinematic variables such as hip and knee joint angles have shown a strong association with power output during the start performance (e.g., Bezodis et al., 2015; Harland & Steele, 1997). The spacing between the foot plates of the starting block also plays a crucial role, allowing sprinters to optimize the push phase and generate substantial forces (Slawinski et al., 2012). Studies have indicated that, in the 'Set' position with fixed plate spacing, a rear knee angle of approximately 90 degrees leads to an increase in block velocity compared to a more extended knee angle from elite to well-trained sprinters (Milanese et al., 2014; Slawinski, 2010). Notably, effective 'Set' positions for sprinters vary based on anthropometric features, muscle strength, morphological characteristics, and motor skills (e.g., Ciacci, 2017).

While numerous quantitative data analyses have aimed to enhance sprint start performance, there is a scarcity of studies using QMD with biomechanical data among elite sprinters. Quantitative approaches alone may fall short in improving athletic performance; an interdisciplinary approach, including QMD, can offer clear and distinct feedback to athletes (McPherson, 1996). QMD provides a systematic and objective approach to analyse and enhance the performance. Biomechanics experts can leverage QMD's four steps – 1) '*Preparation*' is where practitioners acquire knowledge about the participants and crucial movement characteristics. 2) '*Observation*' is the systematic collection of current performance information about the client's movement. 3) '*Evaluation/Diagnosis*' is identifying the strengths and weaknesses of key features of the movement and prioritizing performance improvement. 4) '*Intervention*' is providing appropriate feedback and cues or changing practice conditions that can lead to improved performance of clients (Knudson, 2007). Therefore, the aim of this study was to assess the immediate effect of applying QMD on sprint start performance. The hypothesis was that block exit velocity would be enhanced and joint kinematics would be changed significantly due to the intervention.

METHODS: Thirteen NCAA II sprinters volunteered for the study. Table 1 displays the characteristics of the participants, including their competition events and levels. At the time of data collection, the subjects reported no injuries or illnesses that would influence their performance. All policies and procedures for the use of human subjects were followed and approved by the university's Institutional Review Board.

Table 1: Participant characteristics (mean ± SD).

Characteristics	Male (n = 8)	Female (n = 5)
Age (years)	20.3 ± 1.83	19.0 ± 1.41
Mass (kg)	75.8 ± 7.68	60.0 ± 1.66
Height (m)	1.79 ± 0.06	1.71 ± 0.06
Year of experience in competition (years)	4.5 ± 1.1	5.0 ± 3.0
Personal records (s)	100m (n=6): 10.64-11.5 200m (n=5): 21.57-22.6 400m (n=3): 48.60-52.0	100m (n=2): 12.2-12.4 200m (n=3): 25.3-29.54 400m (n=1): 67.17

Note: Some athletes participated in more than one event.

To align with the application of QMD for coaches and athletes, the crucial kinematics factors related to sprint start performance were organised from peer reviewed meta-analysis and/or review paper as a '*Preparation*' (Table 2). Athletes' characteristics were collected and showed in Table 1. To '*Observe*' (second step of QMD) the pre-intervention performance, two laptop cameras were positioned on both sides of the sprinter (sagittal view) to capture 'Set' posture for analysis. For comparison purpose, the kinematics data were obtained at 200 Hz using 6 Osprey Motion Capture cameras (Motion Analysis Corporation, Santa Rosa, CA, USA). A total of 34 reflective markers (modified Helen Hayes marker set) were used to obtain the kinematics data. All subjects were instructed to use their preferred block setup for three pre-intervention trials. Each trial involved the subject exiting the block from a 'Set' position and covering at least ten meters with maximum effort, simulating a competitive scenario. Two minutes of rest between trials were offered. Images from both sagittal planes were swiftly analysed using *Tracker* (v 5.1.5) to obtain joint angular positions at the hip and knee between the pre-intervention trials. Following a comparison of joint kinematics and block setup with evidence from previous studies (Table 2) to establish the 3rd step of the QMD ('*Evaluation/Diagnosis*'), personalised '*Intervention*' (step 4 of QMD) was designed for each subject. The sequence of intervention provided was as follows: 1) adjust block setup, 2) lead leg side of joint position, and 3) rear leg side of joint position.

Table 2: Feedback/Intervention based on pre-intervention performance.

Variables		Feedback/Cues	Ideal Positions
Block Pedal Spacing		Pedals were adjusted to the outer parameters of the ideal range, depending on their position from the participant's setup. They were further adjusted if needed for other variables.	0.3m to 0.5m apart (e. g., Slawinski et al., 2012)
Lead Leg	**KA**	Move hand position closer to or further from the block.	90 degrees (Ciacci et al., 2017)
	HA	Push your hips towards the ceiling. Move hands closer or further from block.	41 degrees (Mero et al., 1992)
Rear Leg	**KA**	Lower your knee. Push your heel back so it's on the pedal surface.	136 degrees (Slawinski et al., 2010)
	HA	Lower your knee.	80 degrees

	Push your heel back so it's on the pedal surface. Push your hips towards the ceiling. Lean shoulders over/past hands.	(Mero et al., 1992)

Note: cues are only used based on the pre-intervention trials (KA = Knee Angle; HA = Hip Angle).

Participants were given the opportunity to warm-up again as needed between the pre-intervention and post-intervention, and practiced the new block setup and body posture base on QMD's 4th step at least three times until they became comfortable with it. Goniometers were used during practice to ensure subjects maintained the new posture for the post-intervention trials. If subjects struggled to maintain the optimal "set" posture during practice, they were readjusted and asked to practice again. Joint angles were not required to exactly match the ideal positions found in the literature but were adjusted to be as close as possible or toward the feedback provided. After the practice trials, participants performed three post-intervention trials, with feedback repeated as needed between trials to achieve the desired set position established during the intervention.
All trials were cropped from 10 frames before the onset of the movement until 10 frames after the leading leg toe left the block. The instant of toe leaving the block was determined by the moment when the relative velocity between the front pedal marker and the lead leg's 5th metatarsal marker positively increased from 0 m/s. Exit Centre of Mass (CoM) horizontal velocity was determined at the instant the leading leg's 5th metatarsal left the pedal. The knee and hip joint angles at the set position were obtained from the average angles of the twenty frames immediately before the onset of the CoM horizontal movement for all trials.
Values for all dependent variables were averaged across trials of the same type (pre- and post-intervention) for statistical analyses. Normality was assessed using the Shapiro-Wilk test, and paired t-tests were conducted to examine the differences between pre- and post-intervention trials. In the case of any statistical assumption was not met, the nonparametric Wilcoxon test was employed. Due to the inherent limitation of recruiting skilled athletes in sports science research, resulting in a small sample size, a correction for statistical significance was not applied to avoid potential interpretation errors related to a greater Type II error (Sinclair et al., 2013). All statistical significance was set at 0.05.

RESULTS: Data from one of the thirteen subjects was excluded due to data processing issues. All variables met the statistical assumptions for the paired t-test, except for the rear hip angle dataset in the post-test. The intervention yielded a significant effect on four of the seven variables examined (Table 3). Three of the five intervention variables had significant difference between the pre- and post-intervention trials. The lead hip angle significantly decreased from the pre-test to the post-test. Conversely, both the rear knee angle and block space increased significantly from the pre-test to the post-test. However, the lead knee and rear hip joint angles showed no significant difference between the pre-test and post-test.

Table 3: Mean ± SD and effect size of all variables between pre- and post-test.

Variables	Pre-test	Post-test	P-value	Effect Size
Exit Velocity (m/s)	**2.76 ± 0.25**	**2.87 ± 0.21**	**0.041**	**0.43**
Lead Hip Angle (°)	**35.1 ± 4.1**	**31.6 ± 5.0**	**0.004**	**0.86**
Lead Knee Angle (°)	113.3 ± 31.0	113.4 ± 13.6	0.500	0.00
Rear Hip Angle (°)	67.5 ± 14.0	64.37 ± 13.7	0.450	N/A
Rear Knee Angle (°)	**116.8 ± 20.3**	**137.9 ± 16.1**	**0.001**	**1.04**
Time on Block (s)	0.34 ± 0.03	0.34 ± 0.04	0.430	0.09
Block Space (m)	**0.25 ± 0.03**	**0.33 ± 0.02**	**< 0.001**	**2.91**

Note: bold texts represent significant difference between pre- and post-intervention with $p < 0.05$.

DISCUSSION: It is encouraging to see the application of QMD has a moderate effect (d = 0.43) on the sprinting start performance enhancement in this cross-sectional study. The block exit velocity was improved by about 4%. While this may appear marginal, it holds significant weight in determining victory or defeat in a sprint competition, where fractions of a second make all the difference. The QMD procedure offers a systematic plan for assessing and applying current evidence on sprint start performance. Through careful identification and conversion of crucial

factors into cues for adjust starting posture, it successfully modified the lead hip angle (≈10%), rear knee angle (≈18%), and block spacing (≈32%) toward optimal starting position. The fact that the time on the block showed no significant difference implies that the adjustment of these three out of five variables allowed sprinters to exert higher force on the block, resulting in a greater change in velocity based on the impulse-momentum relationship (Bezodis et al., 2015). An intriguing finding was that the average block spacing setup was 0.25 m, falling below the optimal distance within this group of subjects. Upon observation and interaction with the athletes, it was revealed that they were taught to measure block spacing using their feet, which tended to be shorter than the minimal optimal block spacing of 0.3 m as suggested in the literature. Cues to raise the hip higher and adjust hand position effectively minimized the lead leg hip angle. Additionally, cues to lower the rear knee and push the heel to the block pedal successfully increased the rear knee angle, bringing it closer to the optimal rear knee angle.
However, the current study has limitations, including but not limited to: 1) the relatively short session (approximately 15 to 20 minutes) for modifying joint kinematics, 2) the study being conducted on experienced sprinters, making it challenging to change their familiar 'Set' position in a short period, and 3) the absence of a single ideal combination of lower extremity joint kinematics in the 'Set' position (Bezodis et al., 2015; Ciacci et al., 2017). Future studies should undertake longitudinal analyses, considering training, anthropometry, and muscle strength to closely examine the effectiveness of applying evidence-based interventions.

CONCLUSION: This study validates the effectiveness of evidence based QMD on the kinematics of sprint start performance. The observed improvement in exit velocity is particularly encouraging, as it directly impacts the overall performance of skilled sprinters. Given the cross-sectional design of this study, a longitudinal investigation reflecting the progress of the training effect is essential to confirm the effects of QMD more accurately.

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