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Title page

Sprinting Technique and Hamstring Strain Injuries: A Concept Mapping Study.

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Abstract

Objective: The aim of this study was to explore expert opinion to identify the components of sprinting technique they believed to be risk factors for hamstring strain injuries (HSI).

Design: Mixed-method research design.

Methods: The Concept Systems groupwisdom™ web platform was used to analyse and collect data. Participants brainstormed, sorted and rated the components of sprinting technique to consider in a HSI prevention strategy.

Results: Twenty-three experts (academic/researcher, physiotherapist, strength and conditioning coaches and sprint coaches) brainstormed 66 statements that were synthesised and edited to 60 statements. Nineteen participants sorted the statements into clusters and rated them for relative importance and confidence they could be addressed in a hamstring injury prevention program. Multidimensional scaling and cluster analysis identified a 8-cluster solution modified to a 5-cluster solution by the research team: Training prescription (10 statements, mean importance: 3.79 out of 5 and mean confidence: 3.79), Neuromuscular and tendon properties (9, 3.09, 3.08); Kinematics parameters/Technical skills (27, 2.99, 2.98); Kinetics parameters (10, 2.85, 2.92); and Hip mechanics (4, 2.70, 2.63). The statement: "low exposure to maximal sprint running" located in the cluster "Training prescription" received the highest mean importance (4.55) and confidence ratings (4.42) of all statements

Conclusion:

The five clusters of components of sprinting technique believed to be risk factors for HSIs in order of most to least important were: training prescription, neuromuscular and tendon properties, kinematics parameters/technical drills, kinetics parameters and hip mechanics.

Keywords: Hamstring strain, injury, rehabilitation, injury prevention, sprint running, expert opinion

1. Introduction

HSIs are the most prevalent non-contact muscle injury reported in various sports.[1] They have a negative impact on psychosocial wellbeing, potentially on team performance and financial situation of sporting organization.[2, 3] Several risk factors for HSIs have been investigated.[4] Ultimately, older age and previous HSI are the strongest risk factors.[5]

The hamstrings are prone to injury in sports that involve sprinting.[6] Hence, optimising sprinting technique is a HSI prevention strategy worth considering.[7] Although two studies support this suggestion,[8, 9] there is limited evidence supporting sprinting technique as a HSI risk factor. Furthermore, focusing on sprinting technique to prevent HSIs raises the following question: "what specific components of sprinting technique are risk factors for HSIs?". Currently, there is no consensus. If sprinting technique is a risk factor for HSI, we need to identify these components through a rigorous process.

Despite the research undertaken to date, a research-practice gap remains on HSI prevention.[10] To bridge this gap it is recommended to produce research that is closer to the actual practice, in the form of action and participatory research involving different stakeholders.[11] In this context, we employed concept mapping (CM) to integrate experts' knowledge and experience to explore the components contributing to HSI during sprint running. Therefore, the aim of this study is to engage experts to identify the components of sprinting technique they believed to be risk factors for HSIs. The findings from this study will be used to stimulate hypothesis and to guide future research.

2. Methods

CM is a structured process that involves inputs from an identified group on a specific topic. This process results in an interpretable picture of ideas and how these are interrelated.[12] It is a mixed-method participatory approach (i.e. qualitative data collection and quantitative data analysis)[12] that can be used to identify components and to determine which of these components are the most important and actionable from the perspective of the stakeholders. [13] CM involves four steps: preparation, brainstorming, structuring (i.e. statement sorting and rating) and data analysis.[12]

Moreover, CM has been used in other sports injury-related studies [14-16] and has been reported to have good validity and reliability.[17] We used the Concept Systems groupwisdom™ web platform to undertake these steps. The Queensland University of Technology Human Research Ethics Committee approved this research project (approval Number 2000000298).

Participants were considered experts eligible for inclusion if; 1) they had ≥ 5 years' experience working in professional or semi-professional sport organisations as a physiotherapist, strength and conditioning coach (S&C), sport physician, sprint coach and/or academic/researcher; and 2) held qualifications relevant to their role. We used professional networks to identify 50 participants who we approached directly via email and social media platforms (i.e. Twitter and LinkedIn). The 36 experts who volunteered to participate were sent an email invitation including a hyperlink to the study web platform. When logging in to groupwisdom™ the first time, participants provided informed consent. They also provided their age, role(s) within a research/sport organization, the sport(s) they were involved with, the years involved in elite sport/research and relevant qualification(s). This step lasted from mid-May to mid-June 2020.

The focus prompt for brainstorming ideas was: *"Based on your experience, your knowledge on sprinting technique and the research evidence about reducing the risk of sprint-related hamstring injury, what are the components of sprinting technique that you believe are contributing to the risk of HSI?".* Participants could contribute as many ideas as they wanted to. They could see the de-identified ideas contributed by others. Brainstorming lasted one month (until mid-July 2020) and two reminder emails were sent. Before re-opening the web platform, the research team (RK, AD, AS, MW and SD) synthesised the raw brainstormed statements by removing irrelevant statements, splitting compound, identifying duplicate statements and selecting one statement that best captured the essence of the idea. Finally, statements were edited to reflect an agreed meaning without denaturing the participants' words. This process was repeated until the research team agreed that the final statement list included a manageable number of unique, clear and relevant ideas. Following this process, an email including a hyperlink to the structuring step was sent to all participants.

During the structuring step, participants were instructed to sort the synthesised statements into piles that made sense to them. Participants were asked to reflect about how statements related to each other. They were also asked to name each group based on its contents. Instructions stated that each statement should be included within a group and groups like "miscellaneous" or "other" were invalid. Single statement groups were allowed if participants perceived a statement was unrelated to all other statements. Participants were also instructed to use two, five-point scales to rate each statement relative to other statements based on importance and confidence. The importance ratings were generated from the question: "*How important do you believe it is that this characteristic is included in a hamstring injury prevention program?"* (1 = least important to 5 = most important). The confidence ratings were generated from the question: "*How confident are you that this characteristic can be addressed in a hamstring injury prevention program?"* (1 = least confident to 5 = most confident). This step lasted approximately three weeks in August 2020 and two reminder emails were sent.

Before starting the statistical analysis step, we checked that participants had followed the sorting and rating instructions. If the instructions were not followed, the data were removed from the analysis. Concept Systems® groupwisdom™ software (Concept Systems, Incorporated, NY, USA) was used for statistical analysis. This step involved creating a square similarity matrix from the sorted statements followed by applying a two-dimensional multidimensional scaling analysis to position each statement as a point on a X-Y spatial "point map". The distance between the points reflects the degree of similarity between statements. To separate the statements into non-overlapping clusters of related ideas, "cluster maps" were created using a hierarchical cluster analysis.[12] The stress index, an indication of the degree to which the two-dimensional point map represents the participant-generated sorting data was calculated. A lower stress value indicates a better overall fit, with more structure to the data.[12] To decide the most appropriate number of clusters, we followed the guidance from Trochim et al.[18] to scan through the cluster maps from a 10 cluster to a five cluster solution, paying attention to which statements were grouped together as the number of clusters decreased. The research team discussed how to identify the cluster solution that retained the most useful details between clusters while merging statements that conceptually belonged together. If a statement seemed to conceptually belong in an adjacent cluster, the boundaries of the clusters were re-drawn so each statements was located in the cluster in which it was a better conceptual fit.[19]

Mean importance and confidence ratings were calculated for each statement and cluster. Pattern match graphs were created to visually compare mean cluster ratings between rating variables (i.e. importance vs. confidence) and between sprint coaches and academic/researchers. A Welch's t-test was performed to identify statistically significant differences in cluster mean ratings.[20] Finally, we created a two-dimensional Go-Zone graph in which each statement's mean rating (importance and confidence) were plotted. The resulting scatterplot was divided into four quadrants using the overall mean of each rating as the axes. Statements rated above the overall mean for importance and confidence were in the top right quadrant indicating high priority for action to be taken.

3. Results

The majority of participants were male (1 female) aged 43.4 ± 10.6 (mean ± SD) years old with an average of 18 years ± 9.7 (mean ± SD) of experience in their respective role. Participants were mostly involved in a football code and track and field sports. Twenty-seven experts completed the participants questionnaire in which they selected multiple options for their current role and qualifications. Twenty-nine percent were academics/researchers (n=14), 25% physiotherapists (n=12), 18% strength and conditioning coaches (n=9), 23% sprint coaches (n=11) and 4 % others (n=1). Participants reported various formal qualifications including master's degrees (n = 12), doctoral degrees (n = 11) and coaching certifications (n = 11). Twenty-three participants (17% S&C coach, 30% physiotherapist, 30% research/academics and 23% sprint coach) completed the brainstorming to generate 66 statements. After statement synthesis and editing, 60 unique statements were made available to sort and rate. Nineteen participants (14% S&C coach, 34% physiotherapist, 34% research/academics and 18% sprint coach) sorted the 60 synthesized statements into groups (mean number of groups = 6; range, 2 – 11 groups). Two participants' sorting data were excluded from the final analysis as they did not follow instructions (e.g. grouping all the statements into one unnamed pile). Twenty (19% S&C coach, 30% physiotherapist, 30% researchers/academics and 21% sprint coach) and 19 (18% S&C coach, 30% physiotherapist, 30% research/academics and 22% sprint coach) participants rated the statements for importance and confidence, respectively. The four steps of the CM process were completed by 18 participants. (Figure 1-supplementary material)

The mean importance and confidence ratings for all statements were 3.09 and 3.10 out of 5, respectively. Statement 7 *("Low exposure to maximum running speed"*) received the highest mean importance rating (4.55). Statement 7 and 36 ("*Inappropriate training programming*") received the highest mean confidence rating (4.42). Statement 12 (*"Inability to stay low out of the block"*) received the lowest mean importance rating (1.80). Statement 33 (*"Poor vertical force at foot contact"*) and 42 (*"Inadequate hip joint medial rotation"*) received the lowest mean confidence rating (2.40). The mean importance and confidence ratings for all statements are presented in Table 1.

-Insert Table 1-

An eight-cluster map was considered the best representation of the participants' sorting data following the multidimensional scaling and Ward's hierarchical cluster analysis (Figure 2). The map provides a visual representation of the participants' sorting data with each point representing an idea and the distance between each point reflecting how frequently the ideas were sorted together by participants. Statements that were sorted together more frequently are positioned closer to each other on the map (e.g., Statement 36 "Inappropriate training programming" and 37 "Inappropriate training load management" are very close to each other on the map as they were sorted together 17 times while statement 36 and statement 2 "Excessive lumbar extension during high speed running" were far from each other as they were never sorted together). Following discussion amongst the research team, it was agreed that two clusters should be combined to form a *"Kinematics Parameters/Technical skills"* cluster and two other clusters should be combined into a *"Training prescription"* cluster, respectively. The boundary for the *"Neural, muscular and tendon properties"* cluster was redrawn to include statements 30 (*"Poor leg stiffness")* and 32 (*"Insufficient capacity to absorb ground reaction forces"*) while the boundary for the *"Kinetics parameters"* cluster was redrawn to include statements 33 (*"Poor vertical force at foot contact"*) and 60 (*"Increased peak knee joint power absorption during late swing"*). The *"Hip Mechanics"* cluster remained untouched. Ultimately, the research team agreed the resulting five-cluster map retained the most useful details and chose the cluster names informed by the group names given by participants in the sorting step. The *"Training prescription"* cluster received the highest mean importance (3.79) and confidence (3.79) ratings while the *"Hip Mechanics"* cluster received the lowest mean importance (2.70) and confidence rating (2.63) (see Table 1). The stress index value was 0.2125, which is lower than the average stress value across a broad range of CM projects. [17] This indicates that the point map was a better fit with the participant raw sorting data compared to other published CM studies and that the two dimensional configuration of the data in the cluster map was unlikely to be random or without structure.[17] The full list of statements within each cluster, including the four statements that were considered a better conceptual fit in an adjacent cluster, is presented in Table 1.

-*Insert Figure 2 here*-

The Go-Zone graph is presented in Figure 3 (see Table 1 for relevant details of each statement to aid interpretation). The five most important statements were *"Low Exposure to maximum running speed"* (7), *"Inappropriate training load management"* (37), *"Inappropriate training programming"* (36), *"Low exposure to the different phase of high-speed running"* (8) and *"Improper eccentric control of the hamstrings during the swing phase"* (14). The top five statements for confidence were *"Low Exposure to maximum running speed"* (7), *"Inappropriate training programming"* (36), *"Low exposure to the different phase of high-speed running"* (8), *"Inappropriate training load management"* (37) and *"Fatigue"* (13).

-*Insert Figure 3 here*-

The pattern matching showed a high positive correlation (r = 0.99) between mean ratings of importance and confidence across the five clusters with the Welch's t-test showing no statistically significant difference (Figure 4 – Top figure). When comparing the mean rating of each cluster for sprint coaches to academics/researchers, the pattern matching showed a lower positive correlation on importance (r = 0.73) (Figure 4 – Middle figure) and confidence (r = 0.78) (Figure 4 – Bottom figure) (See supplementary material). In addition, the Welch's t-test identified a statistically significant difference between the mean ratings of importance for the *"Kinetics Parameters"* cluster with academics/researchers rating this cluster higher (2.74) than the sprint coaches (2.39) ($p<0.05$) and for the *"Kinematics Parameters/Technical skills"* cluster with the sprint coaches rating this cluster higher (3.21) than academics/researchers (2.88) ($p<0.05$). Similarly, there was a statistically significant difference between the mean rating of confidence for the *"Kinetics parameters"* cluster which academics/researchers (2.70) rated higher compared to sprint coaches (2.16) ($p<0.001$) and the mean rating of confidence for the *"Kinematics Parameters/Technical skills"* cluster which sprint coaches rated higher (3.36) compared to academics/researchers (2.88) ($p<0.001$) (Figure 4- see supplementary material).

4. Discussion

This study is the first to use CM to identify the components of sprinting technique that experts believe to be risk factors for HSIs. The five cluster solution spanned the range of components of sprinting technique identified as risk for HSI (from most to least important): (1) Training prescription, (2) Neuromuscular and tendon properties, (3) Kinematics parameters/Technical skills, (4) Kinetics parameters and (5) Hip mechanics. Only statements from the *"Training prescription"*, *"Neural, muscular and tendon properties"* and *"Kinematics parameters/technical skills"* clusters were in the top right-hand Go-Zone quadrant. Although the focus prompt asked about components of "sprinting technique" that contribute to the risk of HSI, the most important influences on HSI risk were located in *"Training prescription"* cluster that occupies the 1st position in terms of importance and confidence. By contrast, the *"Kinematics parameters/Technical skills"* cluster occupied the third position. In these clusters, the statements which received the highest mean importance and confidence rating were: *"low exposure to maximal sprint running"*, *"improper eccentric control of the hamstrings during the swing phase"* and *"excessive anterior pelvic tilt during high speed running"*. These findings are consistent with current clinical practice recommendations to prevent HSIs[7, 21] and contribute to the controversial topic of sprinting technique as a risk factor for HSIs.

The *"Training prescription"* cluster had 90% of its statements in quadrant 4 of the Go-Zone including the statement *"low exposure to maximal sprint running"* that was rated highest of all statements for both importance and confidence. This indicates that the expert panel strongly believed these constructs should be addressed in HSI prevention programs. Previous research supports the suggestion that training prescription is a key element to prevent HSIs. For example, Duhig et al. [22] showed that elite Australian rules football players exposed to more than their usual high speed running loads across four weeks increased their HSI risk. The association between maximal sprinting exposure and HSIs is also supported by Malone et al. [23] who showed high and low volumes of sprinting exposure are associated with an increased HSI risk. Finally, Ruddy et al. (2018) found that absolute and relative running exposure in elite Australian rules football players increased subsequent HSI risk, albeit, only slightly.[24] The current literature suggests an elevated HSI risk with inappropriate training prescription, supporting the opinion of our experts.

The statement *"improper eccentric control of the hamstrings during the swing phase"* is believed to be an important component of sprinting technique that should be addressed when designing HSI prevention programs. It should be highlighted that participants suggested the term 'improper eccentric control' in response to the focus prompt and its definition was not confirmed. This statement may be interpreted as an improper ability to decelerate the swinging leg during the swing phase that would lead to an excessive hip joint flexion and knee joint extension angles that would in turn result in an excessive eccentric loading of the hamstrings muscle tendon units (MTU) and potentially resulting in a HSI. This deficiency in decelerating the swinging leg may be cause by an undesirable 'intramuscular coordination strategies' of the hamstrings; or lack of 'eccentric hamstring strength'.[25] Furthermore, as intramuscular coordination strategies and eccentric hamstring strength are seemingly inherent, one might see eccentric control as a combination of both. Eccentric hamstring strength has received more attention than eccentric control but has shown inconsistent findings as a risk factor for HSIs.[26] While 'eccentric control' has currently limited evidence. From the available literature, it has been suggested that 'improper' intramuscular coordination strategies, such as overworking biceps femoris and underworking semitendinosus, increase soccer players' susceptibility to HSI.[27] Further, semimembranosus has been shown to compensate during sub-maximal isometric contractions in elite athletes who have previous biceps femoris injuries, which exhibited atrophy likely affecting the muscle's force generating capacity.[28] Individual coordination strategies likely affect preferential muscle activation which could hinder the hamstring MTU's ability to fulfill its 'braking' role during the terminal swing phase. Therefore, it is possible that 'improper' intramuscular coordination may increase individual's propensity for HSI which aligns with the results of this study that experts believe eccentric control of the hamstrings during the swing phase plays a role in preventing injury.

The statement *"excessive anterior pelvic tilt during high speed running"* is also believed to be an important contributor to HSI risk. This is supported by Schuermans and colleagues (2017) who collected trunk and lower-limb kinematics data during sprinting for 29 amateur soccer players. Compared to matched controls, subsequently injured players (n = 4) displayed significantly greater anterior pelvic tilt during the early swing phase.[9] Kenneally-Dabrowski and colleagues (2019) collected trunk and lower-limb kinematics data during the late swing phase of sprinting from 10 professional rugby union players.[8] However, no difference was found for the degree of anterior pelvic tilt between the injured players (n = 3) and the control groups. Therefore, there is currently mixed evidence to support our experts' opinion that *"excessive anterior pelvic tilt during high speed running"* is an important risk factor for HSI.

Although it was not the primary aim of this study, differences were observed between sprint coaches and academics/researchers with respect to mean importance and confidence mean ratings. The academics/researchers group rated the *"Kinetics parameters"* cluster higher, while the sprint coaches rated the *"Kinematics parameters/Technical skills"* cluster higher on importance. These findings are in line with those of Waters et al. (2019) who compared sprint coaches' and biomechanists' perspectives on elite sprinting technique improvement.[29] To the question: "What would you consider elite sprinting technique?", a larger proportion of biomechanists' descriptions were based on kinetics parameters (i.e. stance phase) while a larger proportion of the sprint coaches description were based on kinematics parameters (i.e. posture, body alignment). These findings suggest that sprint coaches and academics/researchers view improving sprinting technique for performance and injury prevention through different lenses. There appeared to be a movement-based (kinematics) analysis for sprint coaches and a force-based (kinetics) analysis for academics/researchers. The divergences also confirm the existing gap between research and practice which highlight the need for more participatory approach to research.[11]

Concept mapping has some limitations around validity, reliability and generalisability of the outcomes, due to non-random sampling, small sample size and reliance on the skills of the researchers.[30, 31] In our project, the subjective judgement of the research team was used to synthesise and edit the brainstormed statements, decide on the number of clusters that best represent the sorted data and reassign some statements to neighbouring clusters. Furthermore, we did not identify perceptions and biases among our study participants, and it is likely that they agreed to participate because they believe sprinting is a risk factor for HSI. Therefore, our findings need to be interpreted with caution. Finally, although we followed and respected Kane and Trochim's instructions,[18] exact replication of this study by another research team may produce slightly different results.

Future research should include more prospective investigation of the components of sprinting technique that have emerged from our findings or combinations of these components as HSI risk factors. Our study has also highlighted the importance of conducting more participatory research involving all the stakeholders (i.e., coaches, academics/researchers and athletes) in the development and implementation of HSI prevention strategies. Subsequent studies investigating the effect of sprinting technique on HSI will likely have improved coach buy-in and the athlete adherence if they incorporate their beliefs. However, this approach should not discourage other exploratory methods with the optimal approach appropriately balancing expert belief and scientific inquiry.

5. Conclusion

Using CM, experts identified five components of sprinting technique they believed to be HSI risk components: Training prescription; Neural, muscular and tendon properties; Kinematics parameters/technical skills; Kinetics parameters; and Hip mechanics. This study also suggests experts believe maximal sprinting exposure is the most important risk factor for HSI. Furthermore, our findings support the importance of implementing a multifactorial evidence-based approach involving all stakeholders to design and implement preventive HSIs strategies.

6. Practical implications

- Our findings suggest the need to closely monitor training prescription during the prevention and/or rehabilitation process of HSIs.

- Hamstring strain injury prevention and/or rehabilitation strategies should be multifactorial and include components highlighted in the five clusters.

- More participatory research is needed involving all stakeholders to ensure the research evidence is relevant to the lived experience of the practitioners and the athletes.

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7. Figure Legends

Figure 1: Flow chart highlighting the 4 steps of the CM process and the number of participants involved per steps.

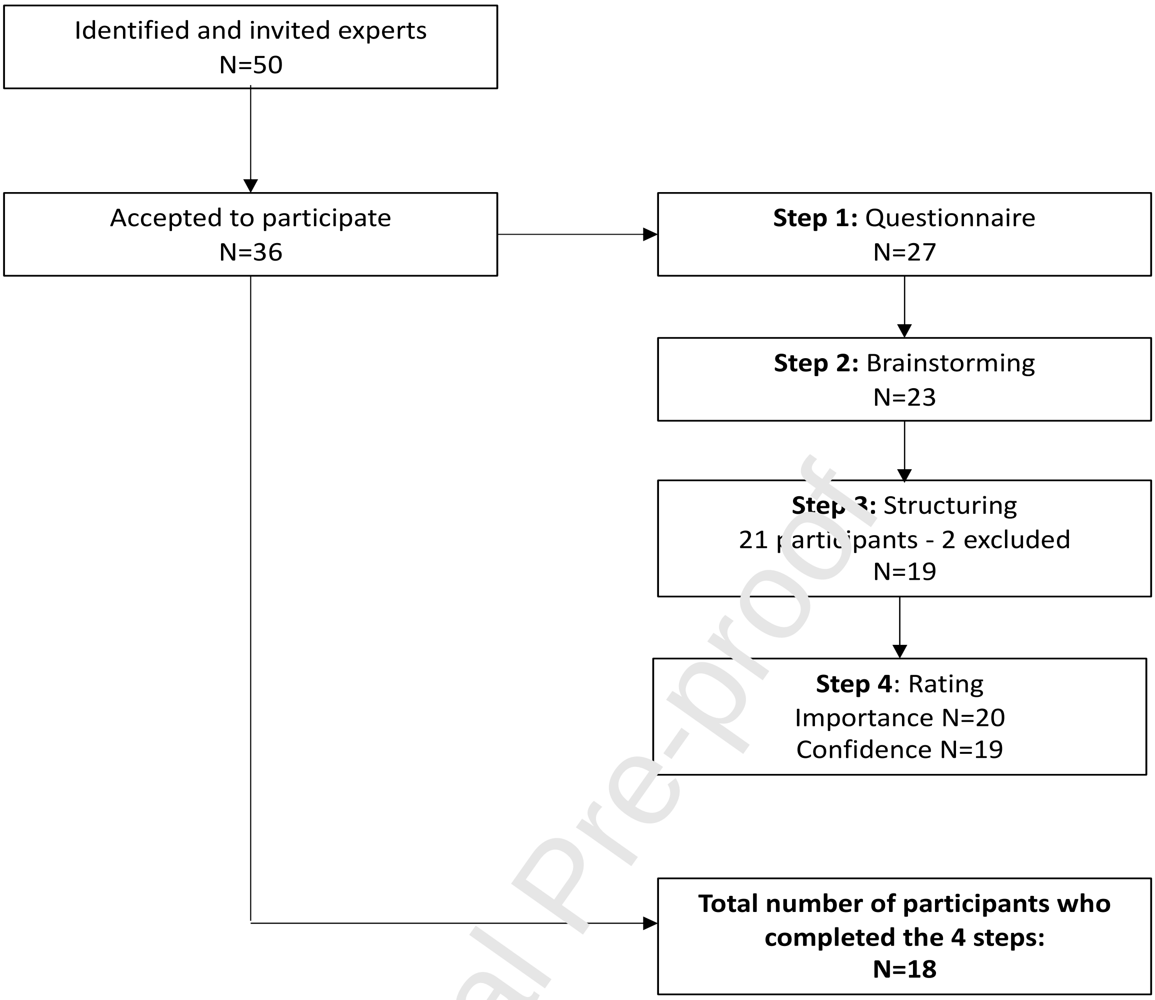
Figure 2*:* Five-cluster map of the aspects of sprinting technique perceived to contribute to the risk of HSI. Dashed lines shapes indicate the original 8-cluster solution.

Figure 3: Go-Zone graph of the aspects of sprinting technique that contribute to the risk of HSI.

Figure 4: (Top) Pattern matching graph for mean cluster ratings between importance and confidence, indicating high agreement between ratings variable (r = 0.99*)*. The mean rating (importance/confidence) for each cluster is 3.79/3.79 for *"Training prescription"*, 3.00/2.99 for *"Kinematics parameters/Technical skills"*, 2.70/2.63 for *"Hip Mechanics"*, 2.83/2.91 for *"Kinetics parameters"* and 3.09/3.08 for *"Neural, muscular and tendon properties"*. There is no significant difference between the mean importance and mean confidence rating for any clusters; **(Middle)** Pattern matching graph comparing mean importance ratings for all five clusters for sprint coaches and academics/Researchers indicating moderate agreement between ratings variables (r = 0.73). The mean rating (sprint coaches/academics-Researches) for each cluster is 3.33/3.58 for *"Training prescription"*, 3.22/2.89 for *"Kinematics parameters/Technical skills"*, 2.50/2.50 for *"Hip Mechanics"*, 2.39/2.74 for *"Kinetics parameters"* and 2.56/2.99 for *"Neural, muscular and tendon properties"*. There is a statistically significant difference for the *"Kinetics parameters"* cluster (p< 0.05) and the *"Kinematics parameters/Technical skills"* cluster (p< 0.05); **(Bottom)** Pattern matching graph comparing mean cluster ratings on confidence between sprint coaches and academics/researchers indicating moderate agreement between ratings varibales (r = *0.78*). The mean rating (sprint coaches/academics-researchers) for each cluster is 3.62/3.55 for *"Training prescription"*, 3.37/2.89 for *"Kinematics parameters/Technical skills"*, 2.50/2.35 for *"Hip Mechanics"*, 2.16/2.70 for *"Kinetics parameters"* and 2.64/2.83 for *"Neural, muscular and tendon properties"*. There is a statistically significant difference for the *"Kinematics Parameters/Technical skills"* (p< 0.001) and for the *"Kinetics parameters"* clusters (p< 0.001).

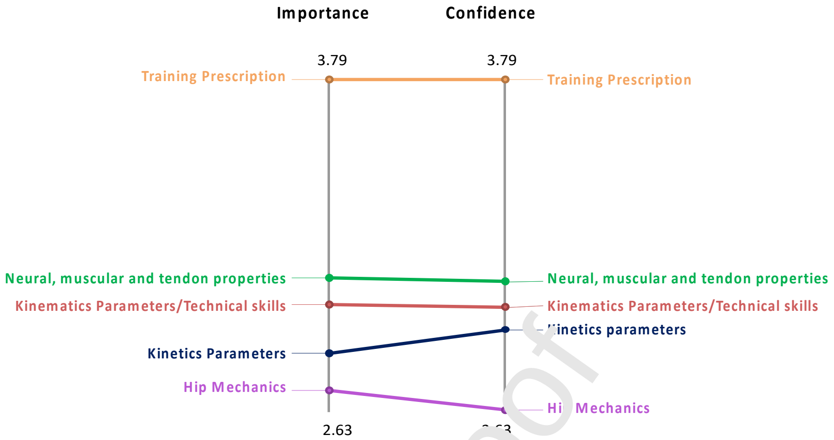
8. Supplementary material

Figure 1


Identified and invited experts
N=50
Accepted to participate
N=36
Step 1: Questionnaire
N=27
Step 2: Brainstorming
N=23
Step 3: Structuring
21 participants - 2 excluded
N=19
Step 4: Rating
Importance N=20
Confidence N=19
Total number of participants who completed the 4 steps:
N=18

1. Figure 4

Top



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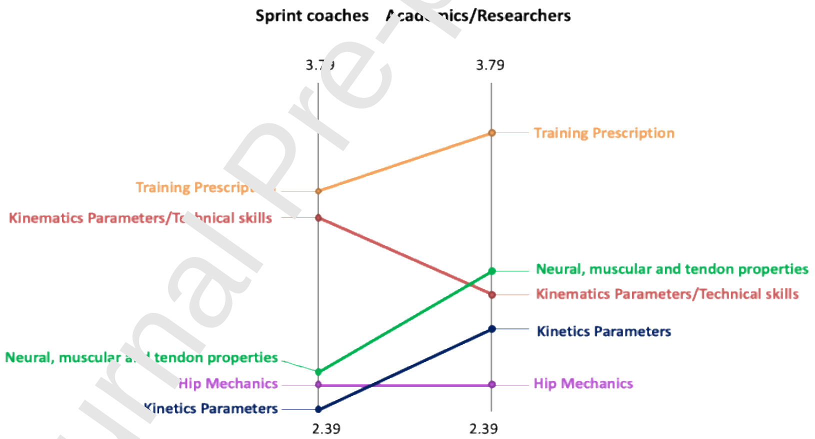

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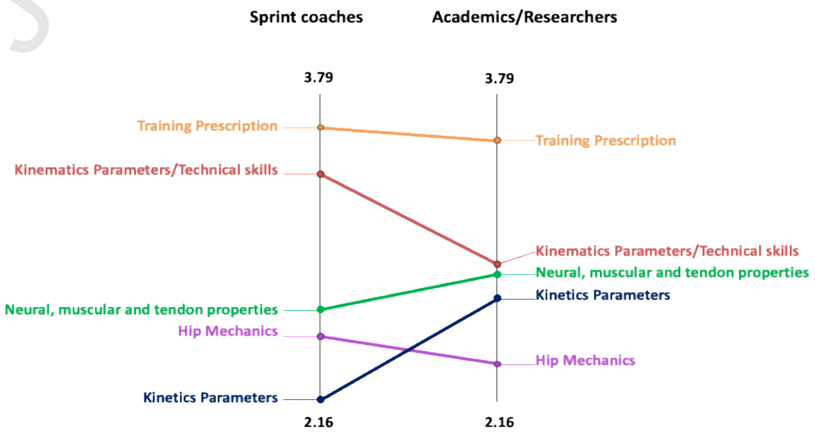

Acknowledgements

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Funding Information

None declared

Declaration of competing interest

None declared

Ethical approval

This research project was approved by the Queensland University of Technology Human Research Ethics Committee (approval Number 2000000293).

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Table 1: Statements generated during the brainstorming process including clusters in which the statement fits, mean importance and confidence ratings, and Go-Zone quadrant for each statement.

		Mean rating (1–5)* for		Go-Zone
		Importance	Confidence	Quadrant [ø]
Training prescription		3.79	3.79	
7	Low exposure to max running speed	4.55	4.42	4
37	Inappropriate training load management	4.50	4.26	4
36	Inappropriate training programming	4.35	4.42	4
8	Low exposure to the different phase of high-speed running (HSR)	4.30	4.36	4
13	Fatigue	3.95	4.00	4
43	Lack of sport specific running technique in training	3.50	3.63	4
29	Poor ability to adapt to external load	3.45	3.68	4
35	Inability to adapt to musculotendinous stress during HSR.	3.35	3.36	4
34	Inability to adapt to musculotendinous strain during HSR.	3.25	3.47	4
11	Poor leg speed capacity	2.70	2.26	1
Neuromuscular and tendon properties		3.09	3.08	
14	Improper eccentric control of the hamstrings during the swing phase	4.25	3.73	4
31	Lack of hamstring eccentric strength during the swing phase	3.95	3.89	4
30[$]	Poor leg stiffness	3.45	2.63	1
54	Poor hamstring neuromuscular recruitment pattern in HSR	3.15	2.78	2
39	Shorter biceps femoris long head fascicle length	3.05	3.57	3
58	Reduced electromyographic (EMG) activity of trunk muscles during HSR	2.75	2.42	1
50	Poor force-velocity profile	2.55	2.94	1
38	Insufficient electromyographic activity of the glute maximus	2.55	2.63	1
32[$]	Insufficient capacity to absorb ground reaction forces	2.40	3.11	3
Kinematics parameters/Technical skills		2.99	2.98	
10	Overstriding pattern	3.80	3.52	4
6	Lack of Lumbopelvic control	3.75	3.22	4
52	Improper hip and knee joint coordination in late swing	3.63	3.47	4
1	Excessive anterior pelvic tilt during high speed running	3.50	3.42	4
15	Improper unfolding of the lower leg in late swing phase	3.45	2.94	2
20	Excessive back kicking of the recovery leg	3.45	3.26	4

5	Lack of trunk control	3.40	3.22	4
17	Improper frontside mechanics	3.35	3.21	4
3	Excessive trunk lean during HSR.	3.30	2.95	2
56	Improper alignment of the hip, knee, ankle joint during HSR.	3.30	2.94	2
19	Excessive hip joint extension of the recovery leg	3.10	3.05	2
16	Improper backside mechanics	3.00	3.21	3
2	Excessive lumbar extension during HSR.	2.95	3.05	1
4	Excessive trunk oscillation on the sagittal plan during HSR.	2.95	2.89	1
48	Excessive lateral pelvis shift	2.95	2.89	1
21	Poor knee cross (recovery leg is behind the stance leg at foot contact	2.90	2.57	1
59	Increase lumbar extension during HSR.	2.90	2.94	1
57	Trunk lateral flexion towards the ipsilateral side during late swing	2.80	2.94	1
28	Excessive plantar flexion at foot contact	2.75	2.73	1
55	Poor capacity to transition from a flexed posture to an upright posture when hitting top speeds	2.75	3.26	3
9	Continued plantar flexion of the recovery leg in the swing phase	2.70	2.68	1
44	Poor ability of team sport athletes to transition from a rotated position to linear sprinting.	2.65	2.84	1
40	Inadequate hip joint flexion range of motion	2.65	2.77	1
18	Excessive knee joint flexion of the recovery leg	2.45	2.73	1
49	Excessive adduction of the standing leg	2.25	2.16	1
45	Poor arm drive	2.25	3.16	3
12	Inability to stay low out of the block	1.80	2.52	1
Kinetics Parameters		2.85	2.92	
24	Reduced hip extensors force generation	3.30	3.21	4
26	Reduced hip extensors power generation	3.25	2.94	2
47	Unbalanced hip flexion-extension strength	2.90	2.89	1
46	Reduced hip abductors strength	2.85	3.57	3
51	Reduced horizontal force output at foot contact	2.85	2.73	1
60$	Increased peak knee joint power absorption during late swing	2.80	2.63	1
25	Reduced hip flexors power generation	2.75	2.94	1
23	Reduced hip flexors force generation	2.70	2.89	1
53	Steeper negative work-velocity profile in the swing phase	2.70	2.47	1
33$	Poor vertical force at foot contact	2.40	2.94	1
Hip Mechanics		2.70	2.63	
41	Inadequate hip joint extension range of motion	2.90	2.73	1

22	Poor hip drive	2.80	2.94	1
27	Improper hip joint separation at toe off	2.60	2.52	1
42	Inadequate hip joint medial rotation	2.40	2.31	1

*1 (least important) to 5 (most important).

Ø Go-Zone quadrants: 4, top right; 3, bottom right;2, top left;1, bottom left.

$Reassigned from their original cluster (see Figure. 1)

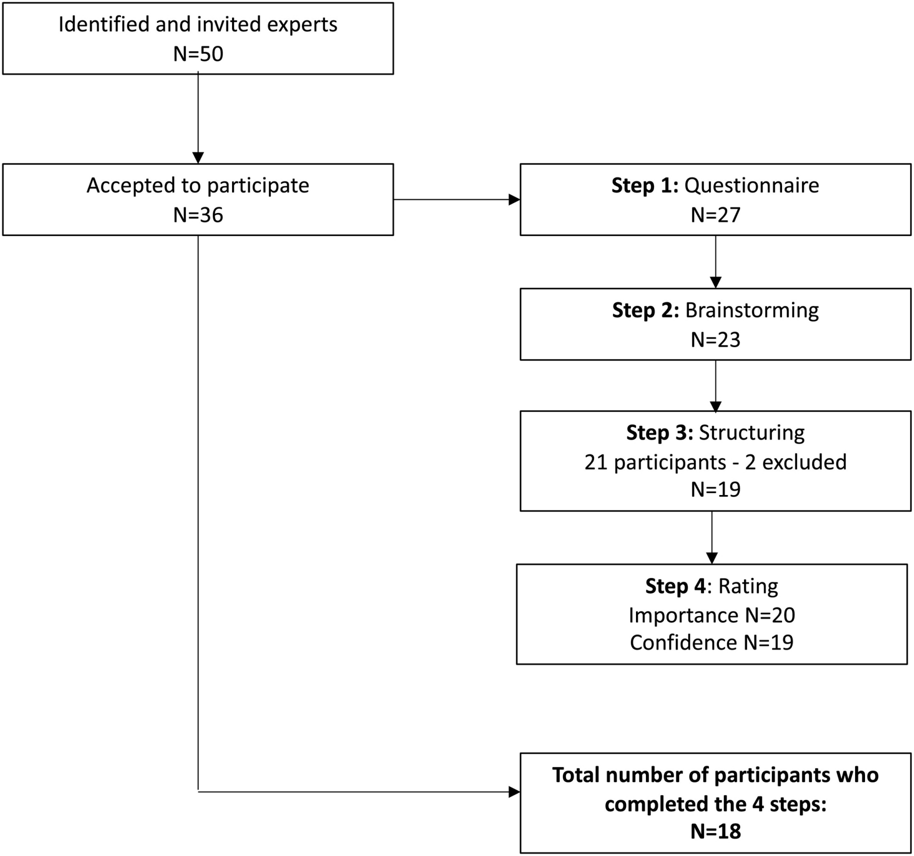
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Figure 1

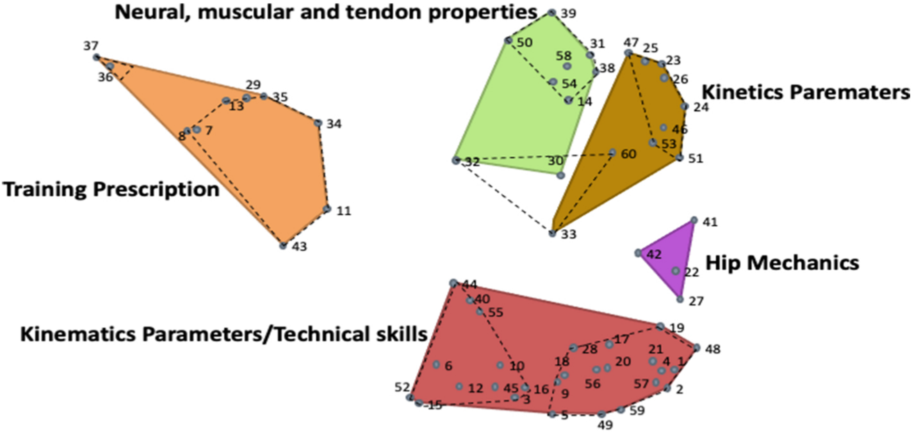
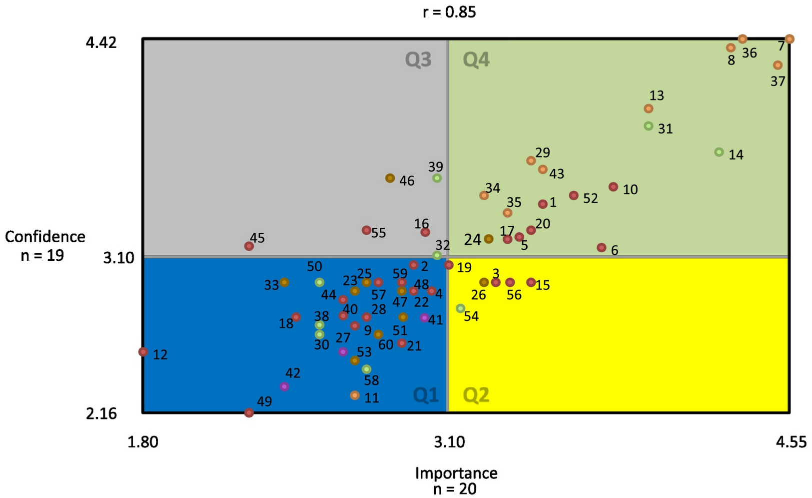

Neural, muscular and tendon properties
Kinetics Parematers
Training Prescription
Hip Mechanics
Kinematics Parameters/Technical skills

Figure 2



<u>Go-zone quadrants</u>

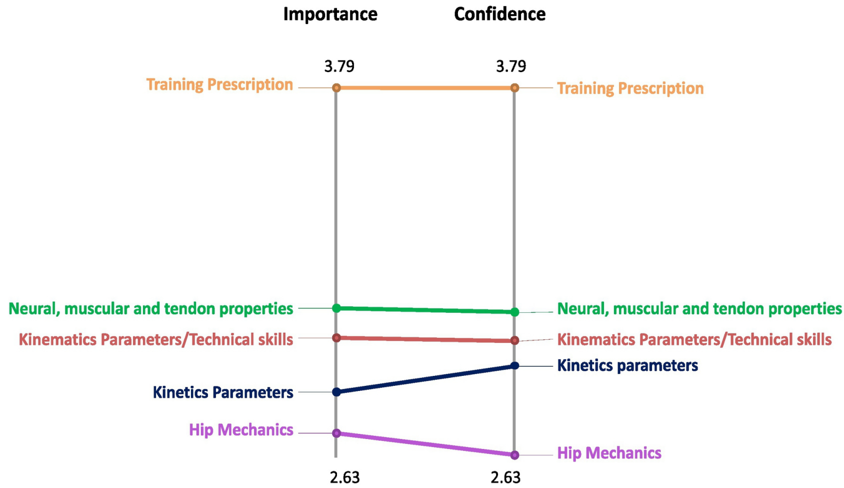
Q4	Statements rated above the overall mean for importance and confidence indicating high priority for action to be taken.
Q3	Statements rated above the overall mean for confidence and below overall mean for importance.
Q2	Statements rated above the overall mean for importance and below overall mean for confidence.
Q1	Statements rated below the overall mean for importance and below overall mean for confidence.

<u>Cluster name</u>

1. Training prescription
2. Neuromuscular and tendon properties
3. Kinematics parameters/Technical skills
4. Kinetics parameters
5. Hip mechanics

Figure 3

Top



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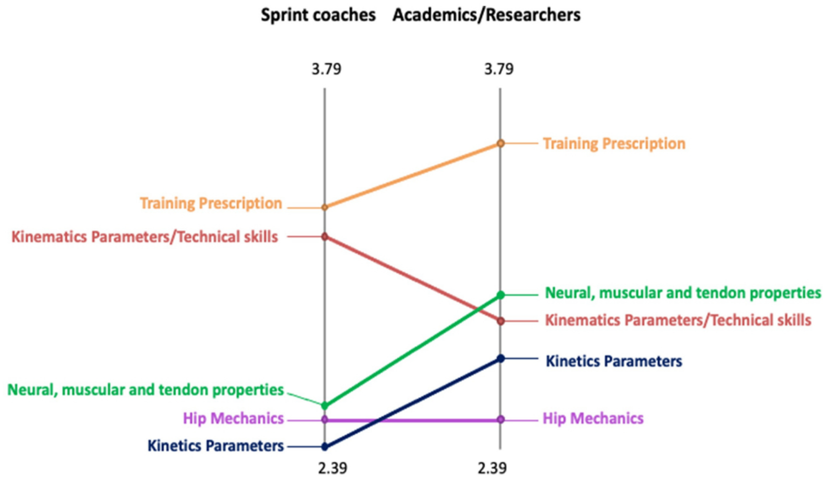

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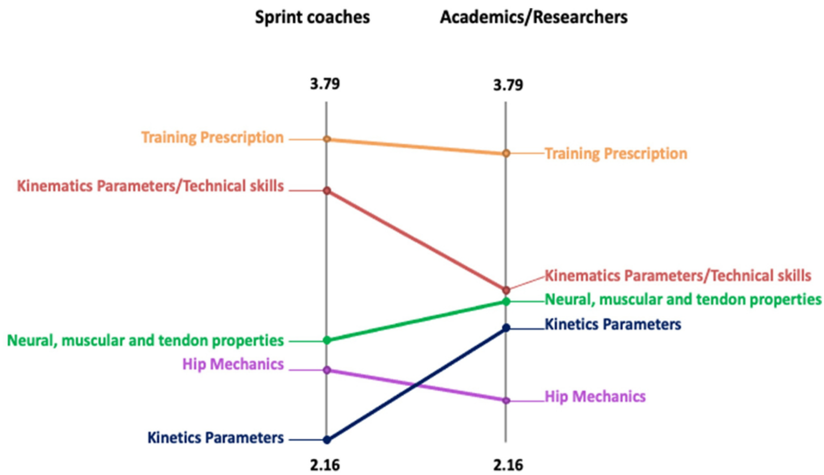

Figure 4