AMPLITUDE EVALUATED WITH HEAD-TOE DISTANCE IN RELATION TO WHERE CIRCLES ARE PERFORMED ON POMMEL HORSE

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Gymnastic judging is likely to integrate an objective measurement, so appropriate performance variables will become critical for fair and valid judging. As noted in literature, head-toe distance (HTD) is a potential variable to evaluate the amplitude of horizontal rotation on pommel horse performances. This study investigates how HTD varies when circles were performed on different positions on the pommel horse. Kinematic data for eight different types of circles performed by three gymnasts were recorded using a Kinect set that was placed above the pommel horse during regular training. As a result, the different profile of HTD were found depending on where the gymnasts performed circles, demonstrating the possible influences of types of circles on HTD. The importance of better understanding and careful use of such a performance variable was emphasised.

KEYWORDS: judging, kinematics, gymnastics, Kinect, rotation.

INTRODUCTION: A radical change to the evaluation system of gymnastics, a representative human-judged sport, may occur. The International Gymnastics Federation announced that artistic gymnastics will adopt a 3D laser sensing system developed by the Japanese company Fujitsu to assist judging processes. This new system was employed partially in the 2019 world championships and will be used more in future competitions including the 2020 Olympic Games. During the first stage of its development, it appeared as though the new system was going to be used only for relatively time-consuming sections of the judging process, namely, computing the difficulty-score, which is basically determined by what skills are performed. However, as the development of the system has progressed, it has become possible that the new system is also going to be used, at least in part, to determine the execution-score, which is an evaluation of how well skills are performed. This may lead to a considerable change to artistic gymnastics.

When quantitative data are employed to evaluate the quality of performance, it is critical to determine the most appropriate and valid variable to represent performance quality. George (2010, p. 27) asserted that movement amplitude of the skill is an important characteristic of refined performances: “The greater the amplitude of the skill, the greater the potential to realise optimum execution.” Although the notion of amplitude may be simple to understand, it may be more difficult and complex to determine what variable the most valid to evaluate the amplitude of skills is. For example, circles on the pommel horse, one of the six events in men’s artistic gymnastics, may be examined (Figure 1). Much literature on coaching and the Code of Points (International Gymnastic Federation, 2017) agree with the idea that great amplitude is desirable for performing circles. However, it may be controversial to determine how to evaluate the amplitude of circles in a quantitative manner.

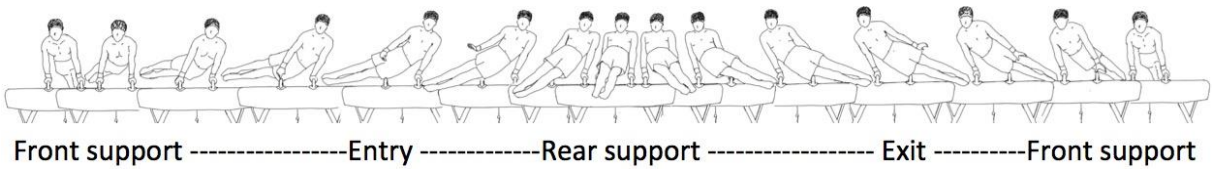

Figure 1: Circles on pommel horse and the definition of phases.

Among several mechanical variables that have been analysed for the amplitude of circles in previous studies, the distance between the head and tip of the toes (HTD) as well as its horizontal version (HTDh) have recently been proposed as simple measures (Fujihara, Gervais, & Irwin, 2019). In comparison with other candidates that are based on the notion of angles or diameters, the advantages of these variables are not only found in their computational

simplicity but also in their conceptual simplicity. HTD and HTDh do not require defining angles, which often inevitably influences computing results, or finding the centre of rotation. Despite their simplicity, their high correlations with human judges' scores reveal their high potential to be used to evaluate the amplitude of circles.

Fujihara et al. (2019) stated that the most valid way to use HTD or HTDh remains unknown. Relying on the mean HTDh of an entire performance and using it as a single criterion for quantifying amplitude may not be the most suitable option. Considering the potential of HTDh as well as the current dynamic situation in the gymnastics community, it is imperative to collect more information about the characteristics of these variables so that they can be used to evaluate performance in a more valid way. In competitions, especially during an optional routine performance, circles can be performed not only on the two handles of the pommel horse but rather all over the pommel horse. In accordance with Fujihara and Gervais (2010) who revealed kinematic differences between two different types of circles, my hypothesis was that HTDh tended to show different characteristics when circles were performed in different positions and orientations on the pommel horse. Clarifying the characteristics of these variables may contribute to discovering a more valid manner of their usage. Consequently, the purpose of this study was to investigate the characteristics of HTD and HTDh during circles in different positions and orientations on the pommel horse.

METHODS: To maximize ecological validity, all the data collection was performed during a regular training session in a gym. The kinematic data required for computing HTD, that is, the three-dimensional coordinates of a head and the tip of the toes were captured with a Kinect V2 device at 30 Hz (Fujihara, 2017). The Kinect was placed 4.58 m above the floor and directly above the centre of a competitive pommel horse, facing downward (Figure 2). The participants in this study included three competitive gymnasts (A, B, and C). Their height, mass, and ages were 1.65, 1.70, 1.68 m, 63.0, 61.0, 67.0 kg, and 29, 21, and 20 years, respectively. The competitive level of gymnast A was higher (expected score > 14.0 without mistakes) than that of B and C (expected score > 12.5 without mistakes). They trained circles regularly in different positions and orientations of the pommel horse as part of their routine work. The kinematic data of eight different types of ten circles (Figure 3) were collected during their regular training sessions without interfering with their performances. All data were collected on the same day. The reason for the small number of participants was partially attributed to the different training routines among the gymnasts and the difficulty of performing circles on some of the eight positions. These data were shared and used for their training. Informed consent for the measurement and usage of their data was obtained.

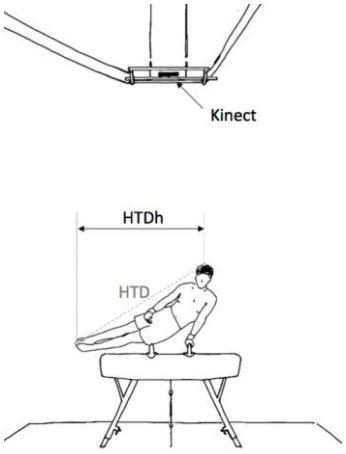

Figure 2: Kinect set above the pommel horse.

The HTDh (Figure 2) was computed as the horizontal distance between the top of the head

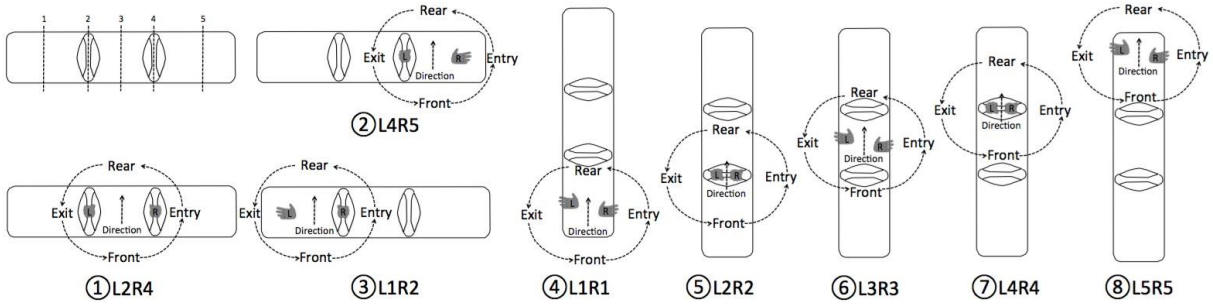

Figure 3: Eight different positions for circles analyzed in the current study. "L" and "R" indicate left and right hands, respectively. The top left figure denotes the position of the pommel horse and the name of circle type indicates the hand placements. For example, L2R4 means that a left hand on position 2, and a right hand on position 4.

and the tip of the toes and was normalised in accordance with the gymnast's body height. In the kinematic data set, while the highest body part during the circles was defined as the top of the head, the part of the body farthest from the top of the head was defined as the tip of the toes. The value of HTD and HTDh were determined at four phases: Front, entry, rear, and exit (Figure 1 and 3) for nine circles from the 2nd to the 10th circles. All the circles were analysed as counter-clockwise circles. Visual inspection confirmed that any invalid data caused by technical problems were excluded from the analysis. For comparisons of the values between the types of circles and between the phases of circles, adjusted Hedge's *g* (Hedge & Olkin, 1985) was computed as an effect size.

RESULTS: Even though the same gymnast performed circles on the same day, the values of HTDh varied depending on the positions and orientations on the pommel horse (Figure 4). All three gymnasts tended to demonstrate the greatest HTDh with circles between the handles (⑥L3R3) and the smallest HTDh with so-called reverse-side circles (③L1R2).
HTDh also varied from phase to phase; generally, HTDh showed a higher value at the phase when the legs pass over the horse compared with its opposite side (②L4R5 Entry vs. Exit: Hedge's *g* = 2.7, 2.7, and 6.0 for gymnast A, B, and C; ③L1R2 Entry vs. Exit: *g* = 9.8, 9.7, and 3.9; ④L1R1 Front vs. Rear: *g* = 1.8, 0.6, and 1.4; ⑧L5R5 Front vs. Rear: *g* = 4.1, 4.2, and 10.5). Generally, HTDh at the front support phase tended to be greater than the other phases.

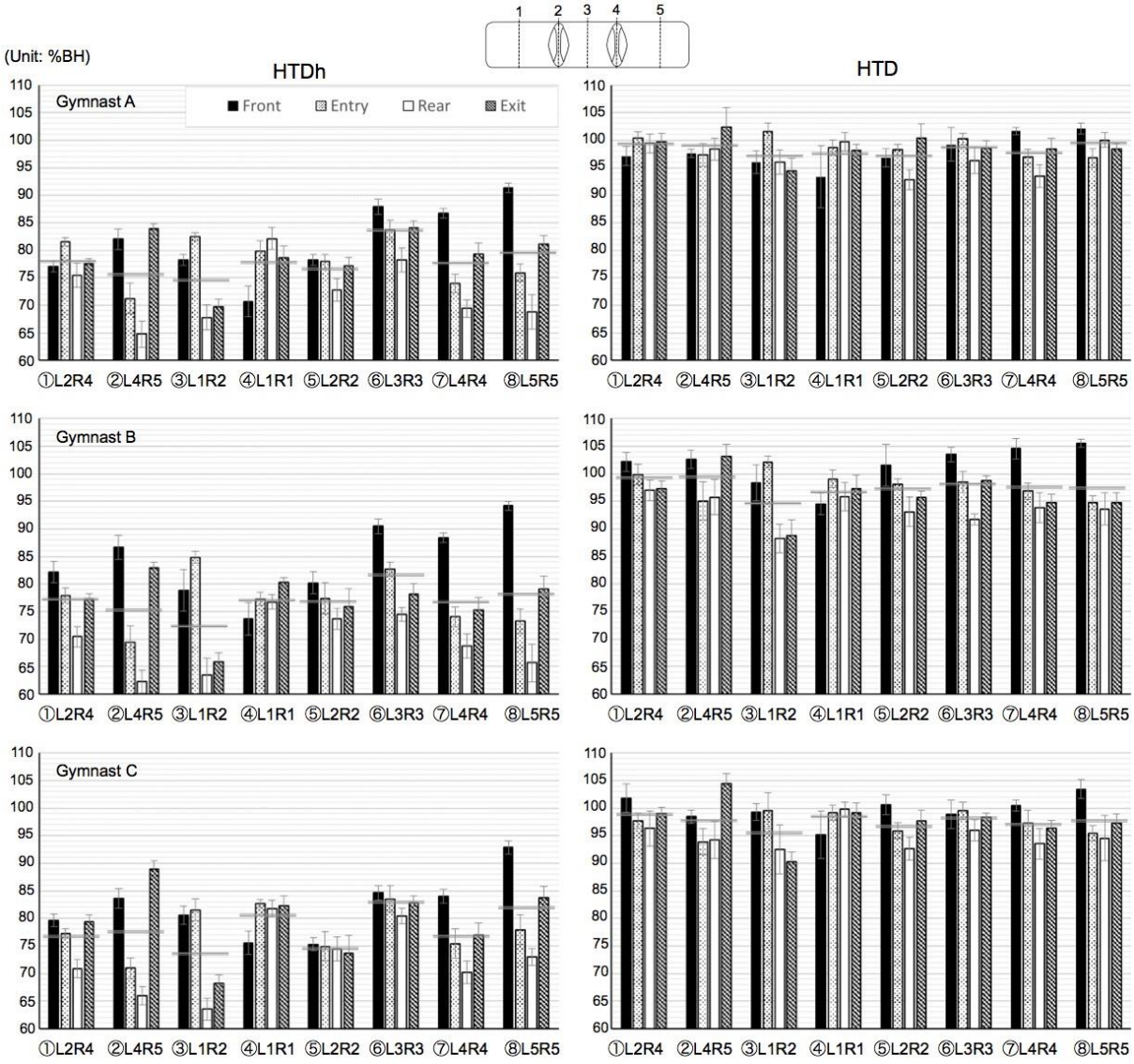

Figure 4: HTDh (left) and HTD (right) for three gymnasts performing circles on eight different positions (①～⑧). The horizontal lines across four bars show the average of four phases.

Consequently, the greatest HTDh was observed with the front support phase of the so-called downhill circles (⑧L5R5). Conversely, the smallest HTDh was found in the rear support, especially in the position ②L4R5 or ③L1R2. In comparison with HTDh, HTD showed relatively consistent values. Because the ankle joints were basically planter flexed, HTD may exceed body height (> 100 %BH) when the body is fully stretched.

DISCUSSION: Although the current data were collected only from three gymnasts, the results clearly revealed that the value of HTDh and HTD during circles tended to vary depending upon the positions and orientations on the pommel horse. The greatest HTDh was achieved during circles between two handles (⑥L3R3). Performing these types of circles is considered more difficult than other types because small-amplitude circles may easily result in a collision with the pommel horse. However, if a gymnast can perform circles there, two handles under the body work as obstacles to force a gymnast to perform high-amplitude circles. By means of informal subjective evaluations by the athletes and their coach, these types of circles were rated the highest (⑥L3R3). On the contrary, so-called reverse-side circles (③L1R2) looked less skilful because their competitive routines do not contain these types of circles.
HTDh tended to increase when the legs passed over the horse and to decrease on the other side where there was no obstacle, namely, the pommel horse. The difference in value between HTDh and HTD became greater in these phases, indicating that the rotation of the body became further from the horizontal plane without changing body alignment. Fujihara and Gervais (2010) noted that gymnasts' feet are lower than the pommel horse when possible without a collision, thus, combining up-down movements into the horizontal rotation of circles. Indeed, the gymnast A's HTD was relatively more consistent throughout four phases for all types of circles than the other gymnasts (Figure 4), indicating that less use of body flexion to let the legs pass over the horse.
It is possible that the gymnasts performed better circles on some positions than others. However, there is a certain position where obtaining higher HTDh is easier. For instance, it appears to be more difficult to achieve high HTDh with circles in side support on the edge of the horse (②L4R5 and ③L1R2) than circles in cross-support on the edge of the horse (④L1R1 and ⑧L5R5). This should be recognised when HTDh is employed as a measure for the amplitude of circles. Another noteworthy aspect is that HTDh tends to increase during the front support phase, which implies that it may be easier to achieve greater HTDh on average with Russian-type skills. Once any criteria are established as a general rule, this kind of discussion will become important from a strategic perspective so as to achieve higher points. More importantly, however, any kind of criteria should be established after enough research and discussion so that fair and valid rules are established for the healthy development of gymnastics. Because new technology will be employed in the gymnastic judging system in the near future, finding valid performance variables are more critical than before.

CONCLUSION: The results collectively demonstrated that HTDh is potentially beneficial to evaluate amplitude of circles in accordance with previous studies. However, not only skill levels but also types of circles have an influence on the values of these variables. Therefore, careless use of HTDh and/or HTD may result in an unfair evaluation of a performance.

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