

## Direction of arm swing of world top-class sprinters in sprint running

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### Abstract:

The purpose of this study was to investigate the direction of arm swing in world-class sprinters and compare it with a previous study done by Hiruma and Kariyama (2019) to provide source material to investigate the best arm swing movements for the future. Fifty-five world-class sprinters (26 males and 29 females) were studied using the observational evaluation method. Taking as a reference a previous study based on the analysis of videos available (Slawinski et al., 2017), in this study, the data were collected from the video-sharing service 'YouTube' provided by Google LLC. Based on the videos collected, five observers—one college and four junior high school track and field coaches, all with more than eight years of experience—observed the direction of the arm swinging motion around the maximum speed phase and rated it as either "longitudinal direction (Type 1)," "Neither longitudinal direction nor lateral direction or cannot be determined (Type 2)," or "lateral direction (Type 3)." The results showed that the percentage of Type 1 was significantly greater than Types 2 and 3 for both males and females. This result differs from previous studies on Japanese athletes which showed that females, unlike males, were more likely to have types 2 and 3 arm swing movement. This means that there is a difference in arm swing direction between world-class female sprinters and Japanese female sprinters. Therefore, we suggest that Japanese female sprinters should aim for a longitudinal arm swing to enhance their performance at the world level. However, it was not possible to clarify the reason for the difference in the direction of arm swing between female world-class sprinters and Japanese female sprinters. Therefore, mechanistic verification of why Types 2 and 3 are so common in Japanese female athletes could potentially provide insights to assist domestic female sprinters in approaching world level status.

**Key Words:** sex differences, coaching, Japanese athletes, 100 m races

### Introduction

To perform well in sprint running, it is important to increase the maximum sprinting speed (Slawinski et al., 2017). Various studies using different approaches have been conducted. In particular, many biomechanics results regarding the movements of the lower limbs have been reported. Noteworthy suggestions include extending support to the hip joint (Ito et al., 1998), increasing the swing speed to the back of the thigh (Mann and Herman, 1985), and reducing the knee joint angle at takeoff (Haugen et al., 2018). Furthermore, a systematic literature review revealed a strong correlation between lower-limb strength, jump ability and sprint running performance (Seitz et al., 2014; Kariyama and Zushi, 2016; Miller et al., 2021).

On the other hand, given that running comprises a series of reciprocal movements of the upper and lower limbs, it has been suggested that the movements of the upper limbs are just as important as those of the lower limbs (Whelan et al., 2016; Macadam et al., 2018). In fact, the arm swing in sprint running plays a role in maintaining the body's balance throughout the run (Hinrichs, 1992; Mann and Herman, 1985; Brooks et al., 2022), and increasing ground reaction force (Ae, 2012; Sayers, 2000), and it is related to the high flight ratio required to improve the sprinting speed (Toyoshima and Sakurai, 2019). In addition, specific arm swinging techniques, which aim at swinging the arms widely and in the longitudinal direction while keeping the elbows flexed, have been developed to increase sprinting speed (Ueya et al., 1992; Hiruma, 2022). As a matter of fact, these findings have been described in instructional books (Tellez et al., 2020), and are now considered standard coaching procedures.

However, recent studies have suggested the need to review these teaching methods. For example, Tamura and Kubota (2004) reported that not only does shoulder joint extension lead to overextension of the synchronized hip joints, resulting in 'leg flow' movements, but also an open elbow joint is desirable to suppress the maximum extension position of the shoulder joint; this conflicts with the theories of 'swinging the arms widely' and 'keeping the elbows flexed'. More recently, Hiruma and Kariyama (2019) demonstrated sex differences in the direction of arm swing. In participants older than junior high school age, the proportion of 'longitudinal direction' increased for males whereas 'lateral direction' was higher for females. Particularly for women, due to their body structure, this relatively higher percentage of 'lateral direction' was identified among the top level Japanese athletes, suggesting that back and forth swing is not necessarily an essential movement.

This contradicts current coaching methods that favor the 'back and forth arm swing' during short-distance running.

Previous studies indicated that the factors affecting sprinting performance differ between males and females (Gleadhill and Nagahara, 2021). It has also been shown that there is a sex difference in sprint ability from early childhood (BOSIO et al. 2017). In addition, running movements (Takabayashi et al., 2017), lower limb movements in one-legged squats and landing movements (Zeller et al., 2003 ; McBride and Nimphius, 2020) all differ between males and females. These studies imply that mechanisms in body movements differ between the sexes when performing similar exercises, thereby suggesting that different approaches may be required for males and females to prevent injury and improve athletic performance. These findings indicate that the results of the previous study (Hiruma and Kariyama, 2019) reporting that arm swing movements to enhance sprinting performance differ between males and females are valid.

Nevertheless, the results achieved by these authors should be carefully interpreted because the participants involved in the investigation were not athletes competing at international level competitions. Actually, none of the female athletes had ever qualified to compete at a world championship. Therefore, these findings alone are insufficient to enable us to conclude whether 'lateral swing of the arms' affects the sprint running performance in female athletes.

Considerable knowledge has been gained by studying the movements of world-class sprinters (Ae, 2012), but investigation of the arm swing direction has been neglected. Consequently, it is necessary to investigate the actual arm swing movements of world-class sprinters, and to consider sex differences as well. To date, no study has been conducted regarding the direction of arm swing of world-class sprinters to elucidate the actual mechanism.

Therefore, this study aimed to investigate the direction of arm swing in world-class sprinters. In the future, we hope to develop a method to examine and determine the ideal arm swing and enhance the teaching process in sprinting.

## Material & methods

### *Participants*

The study included 55 participants (male: 26, female: 29 who competed in the 100 m final race at the Diamond League Games (Eugene 2010, Eugene 2011, 2016, 2017, Lausanne 2012, Oslo 2012, Lausanne 2012, Doha 2016, Rabat 2018, Doha 2018, London 2018, 2019, Birmingham 2019), and the Asian Games (Doha 2019) organized by the International Association of Athletics Federations (IAAF).

### *Procedure*

A previous study based on the analysis of available videos (Slawinski et al., 2017) was used as a reference. In the present study, data were collected from the video-sharing service 'YouTube' provided by Google LLC.

Videos of 100 m races distributed by the organizers of the Olympics, Track and Field World Championships, IAAF Diamond League, and Asian Games, among others were collected and analyzed. Only footages featuring the front view of the runners, whose entire running during maximum speed with confirmed speed maintenance phases (60–80 m) were selected. As a result, 55 athletes who competed in the IAAF Diamond League and at the Asian Games were included for further analysis. The official times recorded and announced by the event organizers were used as the running time of the competitors.

### *Evaluation of the Arm Swinging Motion*

Evaluation of the arm movements followed the same reasoning as a previous study conducted by Hiruma and Kariyama (2019), using the following method:

Based on the videos collected using the above method, five observers (one college and four junior high school track and field coaches), all with over eight years of experience, observed the direction of the arm swinging motion during the maximum speed phase and rated it as either 'longitudinal direction (Type 1)', 'neither longitudinal direction nor lateral direction/cannot be determined (Type 2)', or 'lateral direction (Type 3)'.

In addition, before observation and evaluation of the videos, the following explanation was provided by one examiner as a criterion (guideline) for judging the video images to be " longitudinal direction " or " lateral direction ". " Longitudinal direction " was defined as a movement in which the abduction angle of the shoulder joint is small (the armpits were not open). " Lateral direction " described a movement whereby the abduction angle of the shoulder joint is large (the armpits were open) or the abduction angle of the shoulder joint is small (the armpits were not open), but when swinging backward, the elbow joint is flexed and the forearm (elbow joint) is supinate, or the shoulder joint is externally rotated, and the hand is held away from the body. Subsequently, the results of the five evaluators were summarized, and the swing type was defined by majority consensus. If more than three evaluators provided the same rating, the swing type was so defined; otherwise it was classified as 'Type 2'. Therefore, the recorded swing type means that either the agreement rate of the observers (the highest number of ratings / total number of observers × 100) exceeded 60%, or no agreement at all was reached (i.e. two observers for type 1, two observers for type 2, and one observer for type 3), which in this case was regarded as 'Type 2'. Fig. 1 illustrates typical examples of Types 1–3.

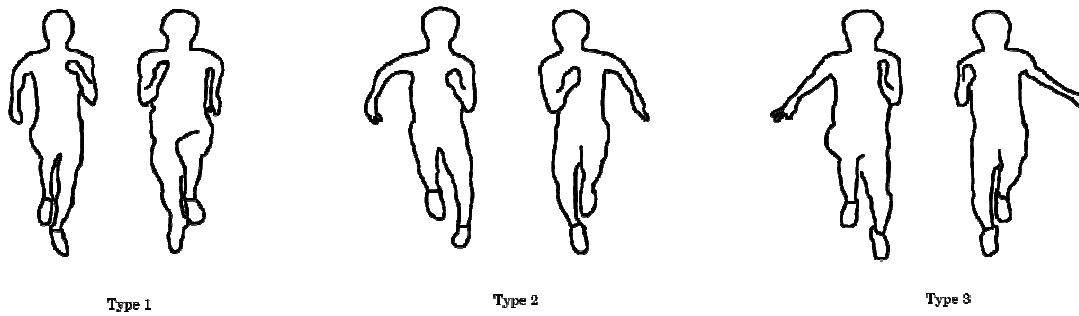


Figure. 1. Typical example of Type1-3.

#### Statistical analyses

Fisher's exact test was used to compare each type and for comparison based on sex differences in each type. Statistical analysis was performed using R software version 3.6.1, and the significance level of the test was set at <5%.

#### Results

Table 1 summarizes the results for agreement of the assessments of the five observers. The mean percentage agreement exceeded 80% for Types 1 and 3 and exceeded 60% for Type 2 in both men and women.

Table 2 presents the results of the evaluation of the direction of arm swing by sex differences. As clearly seen, the world-class sprinters are characterized by a conspicuously high proportion of Type 1 for both males and females. The values were 22 (84.6%) and 23 (79.3%), for male and female athletes, respectively; whereas the percentages for Type 2 were 3 (11.5%) and 5 (17.2%); and for Type 3, 1 (3.8%) and 1 (3.4%), for males and females, respectively. Fisher's exact test revealed significant differences in both males ( $p < 0.001$ ) and females ( $p < 0.001$ ). However, the number of incidences of each type compared by sex revealed no significant differences.

Fig. 2 illustrates the distribution of arm swing direction types and times recorded. All male athletes who ran under 10 s were Type 1, and most female athletes who ran below 11 s (13/15) were Type 1. There were no "Type 3" athletes who recorded these times.

Table 1. Concordance rate of the evaluation results of the three observers.

|        |        | Average match rate (%) | Sample size |
|--------|--------|------------------------|-------------|
| Male   | Type 1 | 88.1 ± 14.1            | 23          |
|        | Type 2 | 66.6 ± 11.5            | 3           |
|        | Type 3 | 80                     | 1           |
| Female | Type 1 | 85.2 ± 15.0            | 23          |
|        | Type 2 | 64.0 ± 8.9             | 5           |
|        | Type 3 | 80                     | 1           |

Table 2. Cross table for sex differences and arm swing type

|        | Male (n=26) | Female (n=29) |      |
|--------|-------------|---------------|------|
| Type 1 | 22 (84.6%)  | 23 (79.3%)    | n.s. |
| Type 2 | 3 (11.5%)   | 5 (17.2%)     |      |
| Type 3 | 1 (3.8%)    | 1 (3.4%)      |      |
|        | $p < 0.001$ | $p < 0.001$   |      |

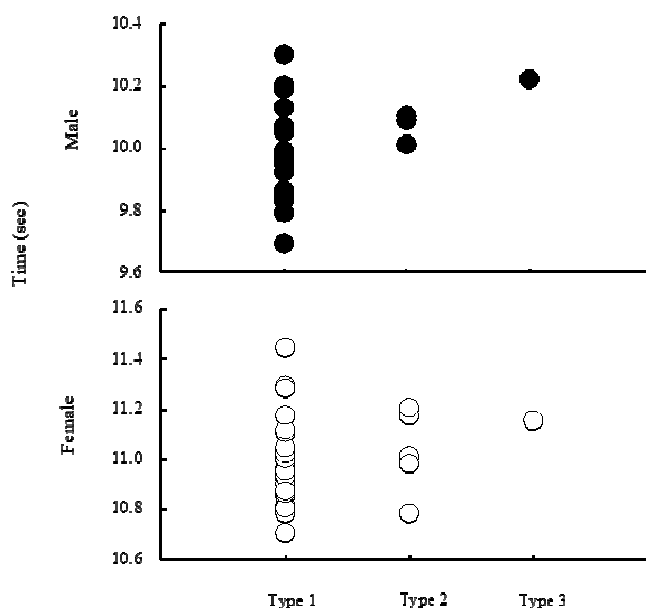


Figure. 2. Arm swing types and distribution of 100m running times.

### Discussion

In this study, five instructors with over eight years of experience coaching athletics performed observational evaluations. The average concordance rate of the evaluations of the five observers was 64.0–88.1% (Table 1). The agreement rate between Types 1 and 3 was high ( $\geq 80\%$  in both cases), which was similar to previous research results (Hiruma and Kariyama, 2019). Therefore, there were no considerable differences in the judgment criteria among evaluators.

For the group ‘World’, the 100 m running times were 9.69–10.22 (mean:  $10.01 \pm 0.14$ ) s for men, and 10.78–11.44 (mean:  $11.00 \pm 0.17$ ) s for women. Note that these values are significantly higher than those of the Japanese short-distance athletes reported in a previous study (Hiruma and Kariyama, 2019). Moreover, given that the latest qualifying standard records for World Games (Tokyo Olympics) are 10.05 s for males and 11.15 s for females; the group ‘World’ definitely comprises world-class sprinters.

The aforementioned results reveal that world-class sprinters exhibited the highest percentage of Type 1 movements, with no sex differences. These results differ from a previous study (Hiruma and Kariyama, 2019) that reported sex differences in the direction of arm swing of Japanese adult sprinters. In the previous study (Hiruma and Kariyama, 2019) that reported the direction of arm swing of Japanese sprint runners ranging from elementary school students up to adult sprinters, for males, the proportion of ‘lateral direction (Type 3)’ decreased as age increased, whereas females exhibited a higher proportion of ‘lateral direction (Type 3)’ after the middle grades of elementary school. Also, there were sex differences among Japanese elite sprinters whereby males exhibited a higher percentage of Type 1 and females displayed higher percentages of Types 2 and 3 arm movements. A comparison of those findings with the results obtained in our study, the data for males are consistent because both Japanese elite sprinters and world-class athletes were essentially ‘Type 1 (vertical)’. However, comparison of females revealed distinct differences. Unlike the female world-class sprinters who were mostly ‘Type 1’, female Japanese elite sprinters were either ‘Type 2’, or ‘Type 3’ oriented sprinters.

As far as the lower limbs are concerned, it was found that muscle strength and muscle cross-sectional area of the knee and hip joints affect performance (Watanabe et al., 2000), which in turn affects lower limb movements during sprinting (Watanabe et al., 2003 ; Ema et al., 2018). Regarding the upper body, it has been reported that muscle strength and muscle mass of the upper body and the muscles that move the arms are important because the rotational forces generated in the lower body, with its large mass, must be counterbalanced by the rotational forces generated by the arm swing (Hinrichs, 1992 ; Young et al., 2001). However, it is unclear to what extent the upper body muscle strength and muscle mass influence the arm swing movements during sprint running. Moreover, Hiruma and Kariyama (2019) discussed the difference between males and females based on investigations showing that females have narrower shoulders relative to their pelvis and less upper body muscle mass relative to the lower body compared to males (Abe et al., 2003). Therefore, it is reasonable to assume that many female sprinters have to increase their moment of inertia around the long axis of the trunk by swinging their arms to the side to counter the large moment created by the lower body. Furthermore, considering that on average Japanese females possess less muscle mass than foreign females (Ishida et al., 1994), it is possible that the muscle mass of the upper body (mass) is more important for Japanese female sprinters to swing their arms back and forth than for male runners. Another key point is that the shoulder width to pelvis ratio may

affect the arm swinging motion during the sprint. Therefore, it cannot be denied that the difference in swing types between Japanese female and world-class sprinters are due to their body characteristics.

However, since these could not be clarified in this study, it will be necessary for future investigations to relate the arm swinging movements to physical strength and morphological characteristics such as differences in upper body muscle mass and physique.

### Conclusions

In this study, the arm swing directions of 55 world-class sprinters (males: 26; females: 29) were analyzed using an observational evaluation method. The results revealed no sex dependent differences, with a higher percentage of longitudinal arm swinging (Type 1) for both male and female world-class athletes. This result differs from previous studies (Hiruma and Kariyama, 2019) involving Japanese athletes that showed that females were more likely to exhibit Types 2 and 3 arm swings.

The present study concludes that there are no sex differences regarding the direction of arm swing of world-class sprinters, and all these elite athletes swing in the longitudinal direction. This means that there is a difference in arm swing direction between world-class female sprinters and Japanese female sprinters. Therefore, we suggest that Japanese female sprinters should aim for a longitudinal arm swing to enhance their performance at the world level.

However, it was not possible to clarify the reason for the difference in the direction of arm swing between female world-class sprinters and Japanese female sprinters. Therefore, mechanistic verification of why Types 2 and 3 are so common in Japanese female athletes could potentially provide insights to assist domestic female sprinters in approaching world level status.

**Conflicts of interest** - The authors declare no conflict of interest.

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