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Retrospective Study; Comparison of the Stride Pattern of Elite 400 meters Hurdlers in Sri Lanka with Elite Athletes in Asia and the World

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ABSTRACT

This study aimed in identifying and comparing the stride pattern in the 400 mH event of the top 10 Sri Lankan, Asian, and World levels athletes of 2019 top list. A retrospective research design was used and following a selective sampling method top 10 athletes were selected from each group as subjects (N 30). Each athlete's 400 mH 2019 season best video was analysed. 400m event timings were recorded from World Athletics. Kinovea software version 0.8.26 and Minitab software version 19 were used for data analysis. One-way ANOVA, Tukey test and Pearson's correlation coefficient tests were performed. It was significantly different from the 1st hurdle to the 6th hurdle in all three groups. Tukey test further revealed a significant difference in Sri Lankan athletes from the start to the 1st hurdle, and from the 6th hurdle to the 10th hurdle. Moreover, only the world-level athletes were significantly different from the 10th hurdle to the finish line. The 400m time was significantly different in all three levels. World-level athletes' group have a moderate, and the Asian-level athlete group have a very weak correlation while the Sri Lankan athlete group have a strong correlation between 400m time and 400 mH time (r= 0.607, 0.135, 0.849) respectively. In conclusion, to improve the level of performance

among Sri Lankan 400mH athletes compared with the other levels, the times taken from start to the first hurdle, between hurdles, and from last hurdle to the finish line needed to be improved while improving 400m performance.
Keywords: Athletics, Hurdles, Track and Field, Stride pattern, 400m hurdle, 400m sprint.

1 Introduction

Athletics is a popular sport that includes running, jumping, and throwing physical movements. Athletics is also referred to as Track and Field and it is evident that even in the ancient era, athletics competitions were included in many human societies and cultures. During the ancient Olympic Games, different running, jumping, and throwing events were contested. Since, the revival of the modern Olympic Games in 1896 it included athletics as one of the sports in the competition program, and at present, there are 48 athletics events contested in the Olympic athletics program. The 400m hurdles (400 mH) event was included in every Olympic program since 1900, since the inaugural World Championships in 1983, since the first Asian Games in 1951 and many other competitions globally. Athletes should clear 10 hurdles placed in the standard distance on a lane of a running track in the 400 mH event. The first hurdle is placed at 45m from the start line of the event. In between two hurdles there is a 35m distance, and from the 10th hurdle to the finish line 40m distance. World Athletics the international governing body of athletics has specified the official height of men's and women's 400 mH events as 91.4cm and 76.2cm respectively (World Athletics. 2020).

The 400 mH race technical competencies are varied, and mainly there are four divisions compared to shorter distance hurdle events. Orderly, start and run to the first hurdle, hurdle clearance movement, running between hurdles, and last hurdle clearance to run into reaching the finish line. Moreover, leg movements have two main technical terms take-off leg (trail leg) and lead leg. The take-off leg is the leg on the ground before a drive into the air. The lead leg is the opposite leg at the take-off, it reaches the hurdle before any part of the body. Movement across the hurdle again can be divided into two parts as the straight and the curve running. Hurdle clearance at the straight is somewhat similar to sprinting hurdles of 100m hurdles or 110m hurdles. However, 'snap/cut-down' action is not required of the lead leg. Otherwise, 'snap/cut-down' may lead the hurdler to fatigue swiftly. Using the left leg as the lead leg advantages the hurdler at the curves because it helps the athlete run close to the inner edge of the lane and it provides less chance to disqualify by breaching the event rules. Running between hurdles shall be referred to as the rhythm of the race, this reflects the stride pattern of the race. Hurdlers need to maintain their sprinting action in a balanced way while clearing the hurdle otherwise it leads to losses of the fluidity and momentum of the athlete. Most athletes believe clearing the 10th hurdle is the finish of the race. However,

athletes still have to go 40m to finish the race. Therefore, athletes need to maintain their rhythm until he/she reaches the finish line (Boyd, 2000).

In the 400 mH event, athletes should accelerate the last few strides, and the last strides before the hurdle should be quick and shorter than the previous stride. The hurdler should be in an erect position with a taller hip in his last stride before the take-off. The quick knee lead is also very important in the take-off position and it led to a full extension of the trail leg in take-off. The result of this action is called a 'delayed trail leg'. If the hurdle is low in height, less forward body lean is sufficient at the top of the hurdle, and vice versa. The trail leg can easily clear lower height hurdles than the higher hurdles. The movement of the trail leg should be continuous forward and upward. It leads to good sprinting action for the hurdler after a clear hurdle. Hurdlers do not need the 'snap/ cut-down' action of the lead leg when they run at low hurdle height, but at high hurdle height, (sprinting hurdle races) hurdlers need the 'snap/ cut-down' action of the lead leg. The hurdler runs in a low-height hurdle should 'glide' or 'float' action. The hurdler should swing back his lead extended arm to maintain body balance while clearing the hurdles. However, athletes should not 'snap' or 'drive' their elbow back. The trailing arm (an arm of the lead leg) should become as soon as smoothly to normal sprinting action when hurdle clearance is finished.

The acceleration and stride pattern of the hurdler to the first hurdle is very important. The hurdler should practice the stride pattern used to cover the first 45m. Most men's elite hurdlers use between 20 to 22 strides to cover the distance from the start to the first hurdle generally. At the start, the athlete who prefers to take off the first hurdle in an even number of strides should place the left leg in the front on the start block while athletes who prefer to take off the first hurdle in an odd number of strides should place their left leg at the rear of the start block. Referring to the 'Lindeman 400m hurdle Theory (1995)' after clearing the first hurdle the ideal stride pattern for running between hurdles is the odd number stride pattern. The odd stride pattern [thirteen (13) strides, fifteen (15) strides, seventeen (17) strides, nineteen (19) strides…] allows the runner to use the same lead leg throughout the race. When hurdlers use an even stride pattern, they have to change their lead leg throughout the race alternatively. It is difficult to maintain the same odd number of stride patterns between the hurdles throughout the race because the hurdler becomes fatigued and they have to move a greater number of stride patterns. When hurdlers run races they change their lead leg alternatively, changes which refer to transitions. Mainly there are three transitions. That is a single alternate, dual alternate, and double-cut down (Lindeman, 1995).

In the single alternative stride, the pattern is if athletes run, use thirteen strides between hurdles by using the left leg as the lead leg and then change it to fourteen strides and use the right leg as a lead leg when the athlete becomes fatigued around the 5th, 6th or 7th hurdle (Lindeman, 1995). This transition method was most suitable for achieving good performance in the race. In the dual alternative stride pattern hurdler run using the left leg as the lead leg and

use thirteen strides between hurdles and change it to fourteen strides and using the right leg as the lead leg as they were comfortable with. Then again change the lead leg to the left leg but use fourteen strides between hurdles. The third stride pattern mostly uses by inexperienced athletes using the double cut-down transition method. Because they can't use alternative lead legs. This kind of athlete's strides is higher. For example, hurdler run using thirteen strides it changes to fifteen strides then it changes to seventeen strides likewise. The reason for this is that hurdlers become fatigued and their stride length becomes shorter. Amature hurdlers use this method. In the 400 mH hurdle race, the athlete who uses the left leg as the lead leg they have more advantage than those who use the right leg as the lead leg. Because athletes use the left leg as the lead leg, they can run closer to the inner lane in the curve than when athletes use the right leg as a lead leg (Lindeman, 1995).

This study was conducted to uncover the possible statistical gaps to have a considerably smaller number of international achievements compared to its available empirical data in the Sri Lankan context. In 1948, Mr. Duncan White won the first-ever Olympic Medal for Sri Lanka (then Ceylon) in London by clocking 51.8 Seconds (International Olympic Committee. 2020. Duncan WHITE). In the year 1950, Mr. White won a gold medal with a new games record at Empire Games now known as the Commonwealth Games which is the only track and field gold medal for Sri Lanka to date. Later, Sri Lanka won a silver medal in the Asian championship clocked 49.44 seconds in the year 2000. Moreover, Sri Lanka has produced several athletes to win medals for this event at the South Asian Federation Games now known as the South Asian Games (SAG). However, Sri Lankan athletes have become unable to win South Asian medals for this event since 2006 and none of the athletes has been able to reach 50 seconds performance since the year 2003 (National Institute of Sports Science, 2020). However, World level athletes and many Asian-level athletes now clock around 47 seconds in performance for 400 mH events. The overall objective of this study was to compare the stride pattern of the 400 mH of Sri Lankan athletes with Asian and World level athletes to find any differences if available. The specific objectives of this study were to identify the 400 mH performance level of the Sri Lankan, Asian, and World level athletes and to identify the 400m flat event performance level of the Sri Lankan hurdlers compared to the Asian and World 400m hurdlers. The 400m hurdle event needs more aerobic contribution than the 400m event (Zouhal et al., 2010). Generally, 400 mH has higher mean velocities than the 110m hurdle race. For example, 400 mH former world record holder Kevin Young clocked 46.78sec had an average velocity of 8.55 m/s and former 110m hurdle world record holder Colin Jackson clocked 12.91sec an average velocity of 8.51 m/s (Lindeman, 1995). Supporting this statement current 110 m hurdle Sri Lanka record which is 13.82sec has a mean velocity of 7.96 m/s while the current 400 mH which is 49.44sec has a mean velocity of 8.09 m/s .

2 Methodology

The study was conducted according to the retrospective research design. Male senior athletes who are competing in 400 mH were the population for the study while among them the study sample of 30 athletes selected who are in the top 10 in Sri Lanka, top 10 in the Asian continent, and top 10 in the World according to the year 2019 World Athletics performance rankings. The year 2019 was the last year where the uninterrupted complete competition season was held before the COVID-19 pandemic when Tokyo 2020 Olympic Games qualification window was open. Data collection was conducted using the selective sampling method. Data were collected via observation based on two main stages. The first stage was collecting the 400m flat timing of the sample. The second stage was collecting two best performance videos of the sample to obtain the most cleared video to calculate their stride pattern between hurdles. To observe the stride pattern, Kinovea (version 0.8.26) software was used which enabled the option of observing slow-motion running videos. The collected data were recorded in Microsoft Word 2013 and Microsoft Excel 2013 packages. The data was analysed by using Minitab 19 software. A normality test was conducted to see the distribution of the data. The data were analysed by one-way ANOVA and group comparisons were done by using Tukey Pairwise Comparison the linear relationship is measured by the Pearson's correlation and the data were presented by using tables, and graphs and described with mean, median, maximum, and minimum values.

3 Results and Discussion

The Shapiro-Wilk test indicated that data were normally distributed. Therefore, parametric tests were used in the present study. Table 01 indicates the performance comparison of the 400 mH, 400m flat, and the time difference between the 400 mH and 400m flat of the sample. The one-way ANOVA revealed that 400 mH time and 400m flat time were significantly different among the three groups ($p=0.001$). However, only the Sri Lankan athlete group were significantly different from the other two groups in the comparison of the time differences between groups. Typically, this time difference is between 2.5sec to 3.5sec range for elite-level male athletes. Currently, there is a 3.75sec time difference between the world 400m flat record and the 400m hurdle record (Dakin, Nick 2003). However, the personal best time difference of the 400m hurdle world record holder is 1.67sec (worldathletics.org, 2020).

Figure 1 shows the average stride pattern between each hurdle of sample groups. The green, orange, and red lines represent the world, Asia, and Sri Lanka respectively. In the men's 400 mH event, athletes should clear ten hurdles at 91.4cm in height. It is essential to maintain high running speed between all 10 hurdles while improving their speed endurance ability. Anaero-

bic glycolytic energy system provides a large contribution to perform without fail. Hurdlers must maintain their running speed while clearing hurdles. The stride pattern adjusting technique of hurdlers is uniquely affected by the 400 mH performance (Otsuka and Isaka, 2019). World's best 400m hurdle runners achieve their average maximum running speed between the 2nd and 3rd hurdle (80m-120m range) and then start to decrease their average maximum running speed step by step. It is shown that clear decrease in their average running speed between the 7th and 8th hurdle (250m-350m range) (Xiaowei, W.X.X, 2006).

Table 1: Performance comparison between Worlds, Asia and Sri Lanka

Variables	World*	Asia*	Sri Lanka*	P-Value
400m hurdle	47.91^{C}	49.06^{B}	52.35^{A}	0.001
400m flat	45.52^{C}	46.91^{B}	48.98^{A}	0.001
Time difference	2.40^{B}	2.15^{B}	3.37^{A}	0.001

* Means with the same superscripts letter are not significantly different

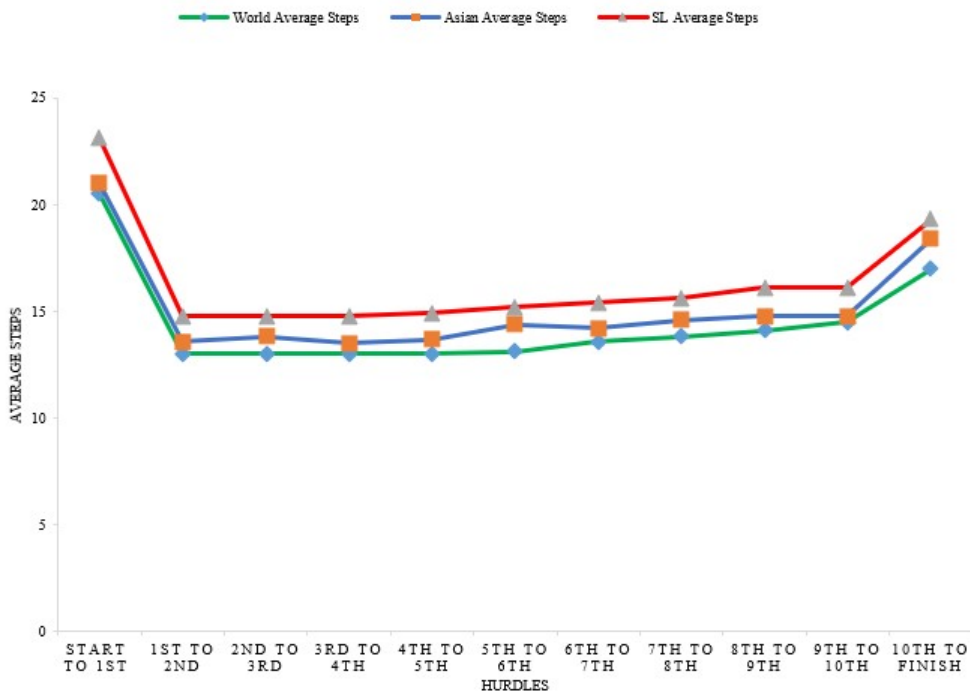

Figure 1: Average stride pattern of World, Asian and Sri Lankan top ten hurdlers

Table 2 shows a comparison of the stride pattern between sample groups. According to the one-way ANOVA, the stride pattern is significantly different among the athletes of three regions (p=0.01). From the start to the 1st hurdle

there was no significant difference between World and Asia. Only Sri Lankan hurdlers show significant differences from World and Asian athletes' groups. There is a significant difference between World, Asian, and Sri Lankan hurdlers in the hurdles until they reached the 6th hurdle respectively. After the 6th hurdle, Sri Lankan hurdlers were significantly different from World and Asian hurdlers until reaching the 10th hurdle and there was no significant difference between World and Asian-level hurdlers as well. From the 10th hurdle to the finish line, only World-level athletes were significantly different from Sri Lankan and Asian athletes groups. There was no significant difference between Asian and Sri Lankan hurdlers between the 10th hurdle to the finish line, except for stride pattern performance level of 400 mH their genetic, and physical pre-dispositions, and the long-term training plan. The best way to develop a good hurdler is by looking for their bio motor abilities to run speed, endurance, strength, coordination, flexibility, and also technics (Iskra, 2012). The stride pattern of hurdlers is a key factor in their hurdle performance. 13 stride rhythm can improve through 20m space running by 7 strides and 14 stride rhythm can improve through 16.5m space running by 6 strides or 21m space running by 8 strides (Boyd, 2000). Charles Moore is known as the pioneer of the thirteen-stride pattern approach between the hurdle and he was the 1952 Olympic 400m hurdle champion. Most of the World's elite 400m hurdlers are now using a 13-stride pattern between the hurdles (World Athletics 2020). The stride pattern is the main factor affecting the rhythm of the race and stride length. Stride length and stride frequency play different roles, the success of the 400m hurdle race relies on balancing these two factors are more important (Manyun, W.X.Z., 2003). According to the analysed results, the number of strides is higher when athletes reach the second half of the race. In the 400mH, fatigue is the most important factor for the increment of the number of strides and hurdle-clearing technique which affects negatively (Krzysztof Przednowek et al., 2016). The time difference between the 400 mH and 400m flat, only the Sri Lanka athletes' group is significantly different from World and Asia athletes' groups. It was found no significant difference between World and Asia athletes' groups in time difference between the two events. However, Bershawn Jackson of the United States indicated there is more importance on the stride pattern of athletes than the stride length in 2005. He clocked 47.30 Sec by running using fifteen strides between the hurdles in the whole race. Before the Bershawn Jackson performance, World believed stride length was more important than stride pattern. Kevin Young and Andre Phillips are the two athletes with the best example of the importance of stride length over the stride pattern. Kevin Young enable to do the only thing Edwin Moses never did was run below the 47 Sec barrier at the 1992 Olympic Games while using a twelve-stride pattern between the 4th and the 5th hurdles. According to the above examples, stride length is more helpful for taller 400m hurdlers, and stride pattern is more helpful for shorter 400m hurdlers (Hurdles First. 2020. More Thoughts about Stride Pattern). In a comparison of the 400m flat with the 400 mH, both events have similar cardiovascular

stress and the 400m flat event requires higher anaerobic glycolytic than the 400 mH event (Gupta, S.., et., al. 1999).

Table 2: Stride pattern comparison between Worlds, Asia, and Sri Lanka

Hurdles	World*	Asia*	Sri Lanka*	P-Value
Start to 1st	20.5^{B}	21^{B}	23.1^{A}	0.001
1st to 2nd	13^{C}	13.6^{B}	14.8^{A}	0.001
2nd to 3rd	13^{C}	13.8^{B}	14.8^{A}	0.001
3rd to 4th	13^{C}	13.5^{B}	14.8^{A}	0.001
4th to 5th	13^{C}	13.7^{B}	14.9^{A}	0.001
5th to 6th	13.1^{C}	14.4^{B}	15.2^{A}	0.001
6th to 7th	13.6^{B}	14.2^{B}	15.4^{A}	0.001
7th to 8th	13.8^{B}	14.6^{B}	15.6^{A}	0.001
8th to 9th	14.1^{B}	14.8^{B}	16.1^{A}	0.001
9th to 10th	14.5^{B}	14.8^{B}	16.1^{A}	0.001
10th to Finish	17^{B}	18.4^{A}	19.3^{A}	0.001

* Means with the same superscripts letter are not significantly different.

Table 03 indicates the correlation of stride between the hurdles vs time spent between the hurdles of World, Asian, and Sri Lankan hurdlers groups respectively. The correlation test conducts between each hurdle at a 95 per cent confidence level. Pearson pairwise correlation test was used to do this analysis. The P-value between each hurdle is less than 0.05 and the test is significant. The Pearson correlation (Pairwise) values from start to 1st hurdle, 1st to 2nd, 2nd to 3rd, 3rd to 4th, 4th to 5th, 5th to 6th, 6th to 7th, 7th to 8th, 8th to 9th, 9th to 10th hurdle and 10th hurdle to finish was 0.611, 0.757, 0.829, 0.811, 0.701, 0.808, 0.515, 0.517, 0.789, 0.596 and 0.857 respectively. According to the values, there was a positive correlation between the stride between each hurdle and with time spent between each hurdle. That means when the stride count increases, time also increases. This positive correlation of stride between each hurdle with time spent between each hurdle negatively affected the athlete's performance. The change in stride pattern is directly influenced by the change in speed between the hurdles, so maintaining stride patterns is more important to maintain overall speed between the hurdles (LI, Hong-Tu and DAI, Yong 2013). The fast split time between the hurdles is determined by the stride frequency of hurdlers and the stride length of the hurdler (Otsuka and Isaka, 2019).

Table 04 indicates the correlation of the 400m flat time with the 400m hurdle time of World, Asian, and Sri Lankan hurdlers separately. The correlation test conducts at a 95 per cent confidence level. The p-value was World, Asian, and Sri Lankan hurdlers took 0.011, 0.043, and 0.002 respectively. There was a strong positive correlation of 0.849 between the 400m flat and 400m hurdle times of Sri Lankan hurdlers and World athletes has a 0.607 moderate positive correlation. However Asian hurdlers have a 0.135 positive very weak correlation between 400m hurdle time and 400m flat time. Evidencing that, when

the 400m flat time increases 400m hurdle time also increases. This positive correlation of 400m flat time with 400m hurdle time also negatively affects the athlete's performance. According to the present study, the significant dif-

Table 3: Correlation of the number of strides between the hurdles and time spent between the hurdles

Hurdles	Pearson Correlation	P-Value
Start to 1st	0.611	0.001
1st to 2nd	0.757	0.001
2nd to 3rd	0.829	0.001
3rd to 4th	0.811	0.001
4th to 5th	0.701	0.001
5th to 6th	0.808	0.001
6th to 7th	0.515	0.004
7th to 8th	0.517	0.003
8th to 9th	0.789	0.001
9th to 10th	0.596	0.001
10th to Finish	0.857	0.001

ference in stride pattern between each hurdle of Sri Lanka with the World and Asia identified, and the significant positive correlation of stride use between the hurdles with time spent between the hurdles identified. A study conducted covering from 1985-2014 thirty-year time period studied the stride pattern of 400 mH by dividing the period into two parts (Group "A" 1985-1999 and Group "B" 2000-2014) and considering the major event conducted between these thirty years. The study was conducted under three parameters which are anthropometric, time parameters, and spatial parameters respectively. The body build parameter includes the height and weight of the athlete, the time parameter includes the split time between the hurdle, and the spatial parameter includes the stride pattern between the hurdles they use. Further, the second parameter revealed that group A athletes (1985-1999) were relatively slow from the start to the first hurdle clearance compared to athlete group B (2000-2014). However, group A athletes were relatively faster from the last hurdle to the finish line in comparison to the athletes from group B. The third parameter only shows one significant difference. Group B athletes' used more strides to cover the distance between the 5th and the 6th hurdles than the athletes from Group A. In contrast, the study did not find any statistically significant difference except the above-mentioned difference (Iskra and Pietrzak, 2015). However, while conducting the present study there were a few limitations to overcome. The major limitation was finding reliable and accurate video footage. Another limitation was finding accurate 400m flat event time of Sri Lankan and Asian level athletes. Importantly, the lack of available literature was another limitation found in this study.

Table 4: Correlation of 400m flat vs 400m hurdle of each region

Category	Correlation (Pairwise)	P-Value
World	0.607	0.011
Asia	0.135	0.043
Sri Lanka	0.849	0.002

4 Conclusion

This retrospective study compared the stride pattern of 30 elite 400m hurdles of the World, Asia, and Sri Lanka. The number of strides from the start to the 1st hurdle, the number of strides between the hurdles, and the number of strides from the 10th hurdle to the finish line were the independent variables and the athlete's performance (time) was the dependent variable. The findings proved World level and Asian-level hurdlers used fewer strides than the Sri Lankan hurdlers to finish the race which results in better times obtained by World and Asian-level athletes. Sri Lankan athletes need to reduce two strides from each instance to par with the other Asian elite athletes to obtain a better performance. Interestingly. There is no considerable difference in stride pattern between the hurdles of the World level hurdlers and Asian-level hurdlers. From the 1st hurdle to the 6th hurdle World level hurdlers have maintained the same median value of stride pattern (13 strides) and Asian-level hurdlers have maintained a 13 to 15 median number of stride pattern. Sri Lankan top ten hurdlers have maintained the same median stride pattern (15 strides) up to the seventh hurdle. The Sri Lankan hurdlers have a relatively better rhythm maintained compared to the other groups. Evidencing that, Sri Lankan athletes should more focus to improve their stride length and bio motor abilities to reduce their stride pattern by one stride to reach the Asian level. After the 6th hurdle World and Asian hurdlers are in the same mean stride level and still Sri Lankan athlete sample needs to reduce one stride to reach the Asian stride pattern. From the 10th hurdle to the finish line World athletes have used 17 strides and the Asian and Sri Lankan hurdlers are at the same level according to their mean stride pattern. But Sri Lankan hurdlers need to reduce their stride pattern by two strides in each phase of the hurdle race to achieve Asian-level medals. In the Lindeman 400-meter hurdle theory, they show the athletes' stride length range according to their stride pattern count. According to that, Sri Lankan hurdlers need a 2.27m-2.13m stride length to run 14-15 strides between the hurdles. But in the future, Sri Lankan hurdlers have a 2.13m-1.98m stride length. That's the reason they run in 15-16 strides between the hurdles.

According to the mean 400m time of three categories, between World and Asia have around a one-second difference. But between Asia and Sri Lanka, there is a two-second time difference. The time difference between the 400m flat and 400m hurdle of World and Asia is in two seconds. However, Sri

Lankan hurdlers have 3 seconds mean time difference. The hurdle-clearing technique of hurdlers is affected by this time difference. A higher different level indicates poor technique competency. Sri Lankan hurdlers need to improve their 400m flat time to win the Asian World level medals.

There is a positive correlation between the strides used between the hurdle and the time spent between the hurdles. That's mean when the stride count increases between the hurdles it leads to a time increment. Sri Lankan hurdlers must reduce their stride pattern between the hurdles to achieve World or Asian-level medals. The stride length of hurdlers, Anthropometric measurement of hurdlers, bio motor abilities of hurdlers, and 400m flat time of hurdlers may affect the stride pattern of hurdlers. Sri Lankan athletes sample need to develop the bio motor ability of hurdlers and need to increase the stride length of hurdlers. In conclusion, Sri Lankan hurdlers should reduce the number of strides taken to achieve better performance than the present performance level and also they need to improve their 400m flat time and compete in 400m flat events.

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