Quantification of Temporal Parameters for Japanese Hopscotch

Arito Yozu*, Kei Nakai*, Akira Matsushita*, Ryoko Takeuchi**, Yukiyo Shimizu**, Yuki Mataki**, Hirotaka Mutsuzaki**, Yutaka Kohno*
*Department of Neurorehabilitation, Ibaraki Prefectural University of Health Sciences Hospital, Japan
**Department of Orthopedic Surgery, Ibaraki Prefectural University of Health Sciences Hospital, Japan
yodu-jscn@umin.net

1 Introduction

Each animal species has its own type of locomotion; dogs use quadrupedalism, Phasmida (a type of insect) use hexapedalism, and humans use bipedalism [1]. Bipedalism is a distinctive feature of humans. In normal humans, for standard locomotion, subjects use symmetrical bipedalism; the time spans of the stance and swing phases are the same between the right and left feet, and the phase difference between them is 50% of the gait cycle (Figure 1) [2,3]. Therefore, the numerical expression of symmetric bipedalism requires only two numbers: the gait cycle and the time span of the stance or swing phase.

In situations, such as hemiplegic gait or split-belt gait, the gait becomes asymmetric (Figure 2). The time spans of the stance and swing phases of the right and left feet become different, and the phase difference between them may not be 50%. Nevertheless, the time span of the cycle of right and left feet is maintained in this situation (Figure 2). Therefore, the numerical expression of this gait requires four numbers: the gait cycle, the time span of the stance or swing phase of one foot, the time span of the stance or swing phase of the other foot, and the phase difference.

“Hopscotch” is a more extraordinary situation. Hopscotch is a popular children’s playground game in which the player hops or jumps through squares marked on the ground. The Japanese version of hopscotch is called “Ken Ken Pa.” The player hops with a single foot in Ken and jumps with the bilateral foot in Pa. The total rhythm is “Ken Ken Pa Ken Pa Ken Pa Ken Ken Pa.” In such a case, the gait is asymmetrical and the cycle is no longer broken (Figure 3). There have been no studies to express this gait in numbers. In this study, we propose how we can define the temporal parameters of Japanese hopscotch.

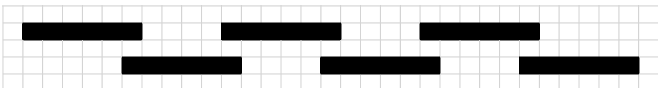

Figure 1: Normal symmetrical bipedalism

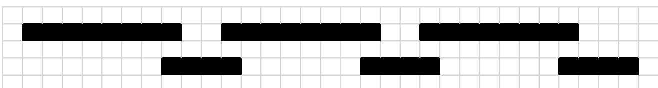

Figure 2: Asymmetrical bipedalism (Gait cycle retained)

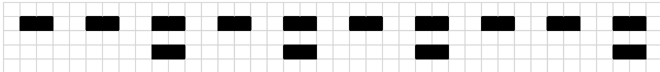

Figure 3: Asymmetrical bipedalism (Japanese hopscotch)

2 Methods

Our goal here is to express the temporal relation of gait events (contact and lift-off of the feet) numerically. We cannot use the concept of “cycle” because there is no repetitive sequence during “Ken Ken Pa.” Therefore, we use a time axis whose origin is the lift-off before the first step. Subsequently, we measure the foot contact (FC) and the time span of the stance phase (StP) for each stance. We measure this parameter for both the right and left feet. A set of the measured parameters below would be proper for the gait, and this set would be the numerical expression of the gait.

(
1st FC of the right foot,
1st StP of the right foot,
1st FC of the left foot,
1st StP of the left foot,
2nd FC of the right foot,
2nd StP of the right foot,
2nd FC of the left foot,
2nd StP of the left foot,
3rd FC of the right foot,
3rd StP of the right foot,
3rd FC of the left foot,
3rd StP of the left foot,
.
.
.
.
)

Here, we wrote in one column, however, we may also use four columns.

3 Results

For example, when the subject is hopping once a second and when each stance is of 0.5 s, the Japanese “Ken Ken Pa Ken Pa Ken Pa Ken Ken Pa” would be expressed as follows:

$$\begin{pmatrix} 1, 0.5, 3, 0.5, \\ 2, 0.5, 5, 0.5, \\ 3, 0.5, 7, 0.5, \\ 4, 0.5, 10, 0.5, \\ 5, 0.5, -, -, \\ 6, 0.5, -, -, \\ 7, 0.5, -, -, \\ 8, 0.5, -, -, \\ 9, 0.5, -, -, \\ 10, 0.5, -, - \end{pmatrix}$$

4 Discussion

We can numerically express the temporal parameters for Japanese Hopscotch in a certain set of numbers (matrix).

The point of our methodology is that we do not need to define the gait cycle. Using this method, we can express any type of asymmetrical bipedalism. We think our method is beneficial for expressing the locomotion of humans or bipedal robots.

References

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