

# Comprehensive locomotion analysis and product evaluation using a treadmill equipped with an integrated force plate

YAMADA Hiroshi\*



## 1 Introduction

Biomechanics is an academic term combining “bio” and “mechanics.” It is the study to analyze and understand human movement and its kinetic forms from a fundamental mechanical perspective. This study requires determining human physical movement from various angles, including the structure and function of muscles that generate forces and the energy supply mechanisms that support them.

The author specializes in biomechanics and sports science and has researched the physical movement and force delivery mechanisms of people of all ages, from athletes to children to the elderly. This article presents the results of a study on various types of locomotion measured using a treadmill equipped with an integrated force plate. It also discusses the possibility of applying these insights to product development and evaluation.

## 2 Running Laboratory SHIP

Tokai University opened a running laboratory called Sports & Health Innovation Plaza (SHIP) as an internal shared research facility in 2018. SHIP promotes interdisciplinary sports and health research across fields. Researches from various faculties within the university, including the School of Physical Education, the School of Health Studies, the Sports Medical Science Research Institute, the School of Science, the School of Engineering, and the School of Medicine, can use the facility. A variety of studies have been conducted to date, including a study on the economy of the running form targeting *Hakone Ekiden* runners and evaluations of the motion functions of patients with scoliosis aimed at improving their quality of life (QOL). These research outcomes are shared with society as scientific insights and provided to university sports clubs to help athletes improve their performance and prevent injury. One of the facility’s major measuring devices is a treadmill

equipped with an integrated force plate. This device enables the measurement of physical parameters under various exercise load conditions, ranging from walking to running, by freely varying the speed of its two belts. A force plate embedded under the belts enables real-time measurement of the floor reaction force applied to the sole (Fig. 1).

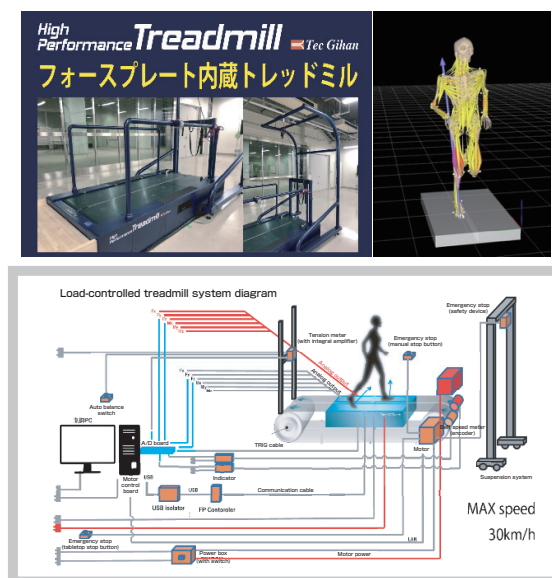


Fig. 1 Treadmill equipped with an integrated force plate

This article introduces three case studies of using the device: “Exploring the True Nature of the Japanese Traditional Nanba Style Running,” “Footwear Suitability: Using Fall Prevention Shoes as an Example,” and “Evaluation of a New Prosthetic Leg Mechanism.” The article presents measurement data and applications of these cases.

## 3 Exploring the True Nature of the Japanese Traditional Nanba Style Running

Nanba is said to be the running style of *Hikyaku*, who were couriers during the Edo period in Japan. This study examined the running movements of lacrosse players holding a lacrosse stick and defined this as “Nanba running.” Then, it compared “Nanba running” to regular running. The results

\* Professor of the School of Physical Education, Tokai University; Director of the Sports Medical Science Research Institute

revealed that Nanba runners exhibited smaller trunk rotation angles and higher floor reaction forces than regular runners (Fig. 2), yet they did not run faster. These results suggest that the Nanba running style is not intended to increase running speed. Rather, it may be a movement style adapted to specific tools or environmental conditions. According to reports, this style is particularly effective in situations involving obstacles or unforeseeable disturbances 1). This aligns with the theory that the style was adapted by *Hikyaku* during the Edo period when roads and streets were not well developed.

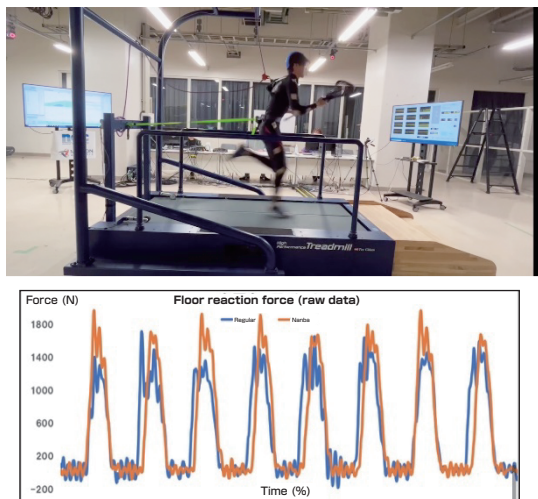


Fig. 2 Floor reaction force during Nanba style running

#### 4 Footwear Suitability: Using Fall Prevention Shoes as an Example

This study examined the suitability of footwear by focusing on the differences in walking motion between regular slippers and nursing care shoes designed to prevent falls. We compared regular slippers and nursing care shoes widely used in care settings, and analyzed lower limb kinematics, particularly changes in ankle joint angles. While no significant difference was found during the stance phase, a significant increase in the dorsiflexion angle was identified during the swing phase when wearing the nursing care shoes (Fig. 3). This is likely due to movements that help prevent stumbling while walking (emphasized dorsiflexion during toe-off)<sup>2)</sup>.

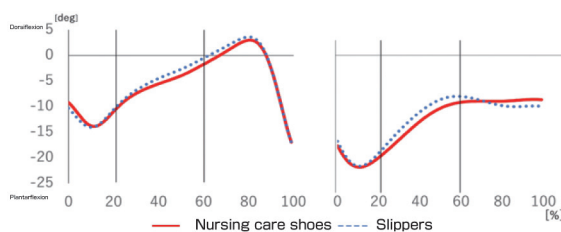


Fig. 3 Ankle joint angle when wearing nursing care shoes (Left: swing phase, Right: stance phase)

#### 5 Evaluation of a New Prosthetic Leg Mechanism

This study evaluated the gait performance of above-knee prosthesis users with new and existing prosthetic mechanisms. Fig. 4 shows toe clearance (vertical distance between the toes and the floor) during the swing phase. Clearance increases with the new prosthetic leg mechanism. These results suggest that subjects may be lifting their entire foot excessively to avoid stumbling.

Going forward, we will optimize the mechanism around the angle joint based on this data to improve the user experience. Additionally, we will analyze the floor reaction force during the stance phase to develop designs that improve walking function overall.

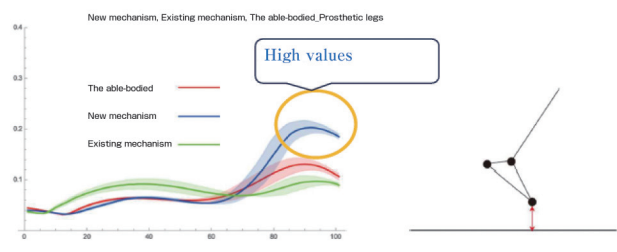


Fig. 4 Toe clearance of prosthetic leg

#### 6 In Closing

This article has described the evaluation of human physical capabilities, the examination of human-product compatibility, and the potential application of these results to product development. Biomechanics and sports science are academic fields that study humans. These fields do not necessarily have a higher impact factor or commercial value than other fields. However, we believe they are extremely significant and useful for manufacturing based on human understanding, as well as for improving safety and comfort. Moving forward, we aim to strengthen our collaborations with companies and industries to implement our research outcomes, thereby contributing to social development and enhancing people's QOL.

#### References

- 1) YAMADA Hiroshi, UCHIYAMA Syuichi, TAKANO Susumu, KIMURA Hideyuki, YAO Norikazu, NAGAO Hideyuki, AOKI Mariko, SHIOZAKI Tomomi, OGAWARA Keita, MIYAZAKI Seiji: "The effect of different styles of running on the ability to turn—A study of the biomechanical efficacy of 'Namba'-style running-" Tokai University Journal of Sports Medicine and Science, No.35, pp.17-24, 2023.
- 2) IGARASHI Kenta, YAMADA Hiroshi, KOGANEZAWA Koichi: "Difference of lower limb control by foot strike pattern during walking on irregular surface," Journal of the Society of Biomechanisms, No.44, pp.179-186, 2020.