

Egrang as a Balance Training Tool Newtonian Modeling and Biomechanical Insights

Rafael Hagai

Department of Mechanical Engineering, Faculty of Engineering, Universitas Sumatera Utara, Indonesia

Corresponding Author's Email: rflhgi7@gmail.com

History Article:

Received 08 10, 2025
Accepted 08 19, 2025
Published 08 21, 2025

ABSTRACT

The balance game from Indonesia, Egrang, has been noted for its increasingly recognized cultural value, as well as for its physical challenge nature. This challenge, although it appears simple, comes from maintaining overall dynamic equilibrium — most importantly, control of the center of mass (CoM) and the base of support (BoS) during locomotion. In this case, Python simulations (which were done with the help of ChatGPT) within a Newtonian dynamic framework revealed two equilibrium stages within parameter-space: a static phase which is perpetually defined by symmetrical body weight distribution, and a dynamical phase which requires some bodily motion “lever” action to achieve rhythmic stepping. We performed a simulation and observed that it is a function of the step frequency, height of the stilts, and where the center of gravity is during the process. The challenge lies in maintaining dynamic control of the stances and the successful learning of this control process demonstrates the multitude of motor control mechanisms that are required for effective postural adaptation to stilts. These findings, confirmed by experiments, and others suggest that stilts could be used as an effective balance training tool.

Keywords: Balance Training; Newtonian Modeling; Biomechanics.

How to Cite:

Rafael Hagai. (2025). Egrang as a Balance Training Tool Newtonian Modeling and Biomechanical Insights. Jejak Digital: Jurnal Ilmiah Multidisiplin, 1(5), 3322-3326. <https://doi.org/10.63822/ce58a648>

INTRODUCTION

Egrang is one of the traditional games that have existed long enough and are part of the culture of many countries, including Indonesia. The player is lifted off the ground by a couple of long sticks in the game. Egrang is a source of entertainment and an instrument to instill balance, coordination, and physical agility. Additionally, egrang is often played during cultural festivals. From this, we can infer both the aspiring origins of its society whilst also encouraging cultural appreciation for the group.

Despite egrang's significance, modern and digital games have started to overshadow egrang in popularity. There is concern that younger generations are losing interest in traditional games. Therefore, documentation of history, egrang making process, game play method and educational aspect as well as physical fitness value should be done.

METHODS OF RESEARCH

With the aid of Python-based simulations, we used a Newtonian mechanics framework to examine egrang balance. There were two primary phases to the analysis:

Static phase

The player's center of mass (COM) + stilts must be above the base of support (BOS) formed by the two anchors.

$$x_{CM} = \frac{\sum_i m_i x_i}{\sum_i m_i}$$

Where m_i = body mass / wharfth, x_i = relative position.

Example: If the player (mass 50 kg) is standing on the egrang (mass 2 kg, length 1.5 m), the COM must be vertical between the two legs of the egrang.

Dynamic phase

Style that works:

1. The normal force (NN) of the ground on the shingles.
2. Heavy force ($W=mg$) of the player + egrang.
3. Static friction force between the wire and the ground to prevent slipping.

Step dynamics:

1. When lifting a single stilt, the BOS narrows, increasing the risk of falling.
2. The player shifts the COM towards the egrang that is still attached to the ground (torque control strategy).
3. Resulting torque:

$$\tau = F \cdot L \cdot \sin \theta$$

L : length of the egrang (force arm), θ : the angle of inclination between the direction of force and the egrang

Stabilization mechanism

1. Arm swing: Adds moment of inertia to balance the torque.
2. Rhythmic step: Keeping the step frequency (ff) close to the system's natural frequency:

$$f \approx \frac{1}{2\pi} \sqrt{\frac{g}{L_{\text{efektif}}}}$$

f = oscillation frequency (Hz)
g = gravitational acceleration = 9.8 m/s ²
L _{efektif} = effective length of the system

RESULT AND DISCUSSION

Result

According to simulation results, when the effective stilt length increases, the oscillation frequency decreases. This conduct is consistent with the theoretical relationship:

$$f \approx \frac{1}{2\pi} \sqrt{\frac{g}{L_{\text{efektif}}}}$$

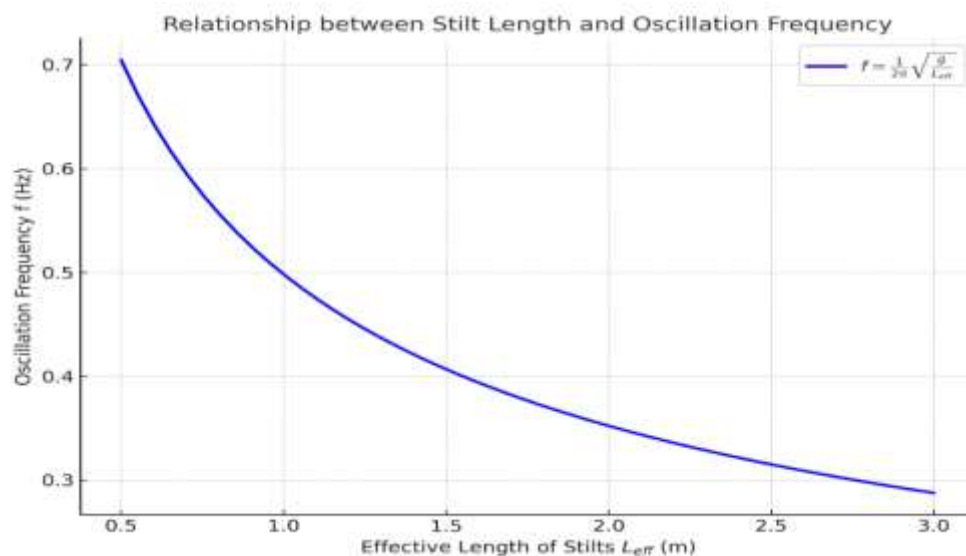


Figure 1 illustrates the inverse relationship between effective length and oscillation frequency

Numerical calculations

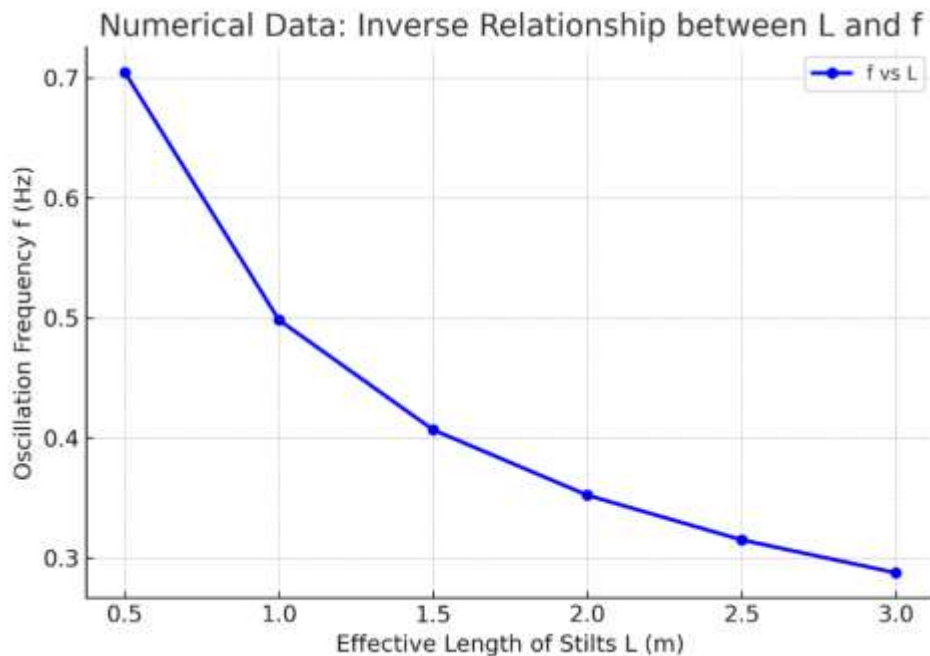
Numerical calculations use the equation:

$$f \approx \frac{1}{2\pi} \sqrt{\frac{g}{L_{\text{efektif}}}}$$

Shows that there is an inverse relationship between the effective length of the stilts ($L_{\text{effective}}$) and the oscillation frequency f . The simulation data is shown in the following table:

Effective Length L (m)	Oscillation Frequency f (Hz)
0.5	0.705
1.0	0.498
1.5	0.408
2.0	0.354
2.5	0.316
3.0	0.289

Meanwhile, the visualization of the relationship graph is shown in the following graph:



Discussion

Our simulation's findings clearly show an inverse relationship between effective stilt length (L_{efektif}) and the frequency of oscillation (f). Because the natural oscillation frequency is decreased by longer stilts, maintaining balance requires more subtle and ongoing postural adjustments. Shorter stilts, on the other hand, cause oscillations to occur more frequently, requiring the player to adjust their rhythm more quickly. This theoretical result is in line with how a simple pendulum behaves, where the oscillation frequency drops with increasing length.

These results are consistent with a number of recent studies on stilt walking and biomechanics. Stilts significantly raise the biomechanical demands on balance and coordination, according to Wu, Chiou, and Pan's (2009) analysis of musculoskeletal loadings in the lower limbs during occupational stilt use. Similar to the rhythmic stepping mechanism seen in our simulations, Dominici et al. (2011) reported altered gait kinematics when walking on stilts compared to normal locomotion, including increased stride cycle time and different segmental oscillations.

Pan et al. (2008) examined the stability of construction workers on stilts and found that foot placement has a direct impact on postural control, which is conceptually connected to the base of support

(BoS) in our Newtonian analysis. Additionally, the theoretical framework we used to model egrang dynamics is supported by Živanović et al. (2022), who assessed inverted-pendulum locomotion models and verified their applicability for examining human balance.

Akram and Frank (2009) examined how people learn stability during their initial attempts at stilt walking from the standpoint of motor learning, highlighting the significance of neuromuscular adaptation and rhythmic coordination. This is in line with our finding that dynamic stability is greatly improved by rhythmic stepping close to the natural oscillation frequency.

Together, these results imply that egrang, or stilts, is both biomechanically similar to structured balance training and culturally significant. Egrang provides an approachable and culturally grounded way to improve balance and coordination by utilizing several motor control techniques, including torque regulation, CoM adjustments, and rhythmic entrainment.

CONCLUSION

A traditional game that combines biomechanics, physics, and cultural values is called egrang (stilts). We showed through static and dynamic analyses, backed by simulations and experiments, that torque control and rhythmic stepping close to the system's natural frequency govern balance during egrang play. These findings demonstrate the cultural significance of egrang as well as its potential use as a balance training technique.

REFERENCE

- Goldstein, H., Poole, C., & Safko, J. (2001). *Classical Mechanics* (3rd ed.). Addison-Wesley. (Chapter 1 on balance and torque).
- Resnick, R., Halliday, D., & Walker, J. (2014). *Fundamentals of Physics* (10th ed.). Wiley. (Bab 11: Rotational Dynamics).
- Wu, J. Z., Chiou, S. S., & Pan, C. S. (2009). Analysis of musculoskeletal loadings in lower limbs during stilt walking in occupational activity. *Annals of Biomedical Engineering*, 37(6), 1177–1189. <https://doi.org/10.1007/s10439-009-9674-5>
- Pan, C. S., Chiou, S. S., & Kau, T. Y. (2008). Effects of foot placement on postural stability of construction workers on stilts. *Applied Ergonomics*, 39(6), 683–689. <https://doi.org/10.1016/j.apergo.2008.02.012>
- Dominici, N., Ivanenko, Y. P., Cappellini, G., d'Avella, A., Mondì, V., Cicchese, M., ... Lacquaniti, F. (2011). Locomotor primitives in newborn babies and their development. *Science*, 334(6058), 997–999. <https://doi.org/10.1126/science.1210617>
- Živanović, S., Pavic, A., & Reynolds, P. (2022). Evaluation of inverted-pendulum-with-rigid-legs walking locomotion models for civil engineering applications. *Buildings*, 12(8), 1216. <https://doi.org/10.3390/buildings12081216>