Biomechanics Analysis of Elementary School Students’ Fundamental Movement Skill (FMS)

Muchamad Arif Al Ardha¹,*, Chung Bing Yang², Nurhasan³, Dwi Cahyo Kartiko⁴, Bambang Ferianto Tjahyo Kuntjoro⁵, Kolektus Oky Ristanto⁶, Andhega Wijaya⁷, Kartika Rinakiti Adhe⁸, Kukuh Pambuka Putra⁹, Fajar Awang Irawan¹⁰, Rizky Patria Nevangga¹¹, Niken Sasadhara Sasmita¹², Ainun Zulfikar Rizki¹³

¹,³,⁴,⁵,⁶,⁷ Physical Education Department, Universitas Negeri Surabaya, Indonesia  
² Physical Education and Kinesiology Department, National Dong Hwa University, Taiwan  
⁸ Early Childhood Education Department, Universitas Negeri Surabaya, Indonesia  
⁹ Faculty of Medicine and Health Science, Universitas Kristen Satya Wacana, Indonesia  
¹⁰ Sports Science Department, Universitas Negeri Semarang, Indonesia  
¹¹,¹² Sport Coaching Education Department, Universitas Negeri Surabaya, Indonesia  
¹³ Master Program in Sport Education, Universitas Negeri Surabaya, Indonesia  
*Corresponding author. Email: muchamadalardha@unesa.ac.id

ABSTRACT

Fundamental movements are part of teaching objectives in the physical education curriculum for elementary school students. This study aimed to analyze the elementary school students’ basic movement skills (FMS) using the kinematic approach. The fundamental movements in this research were correlated with lower body parts, i.e., one leg standing position with closed eyes (non-locomotor), hopping (locomotor), running (locomotor), and kicking (manipulative). This was comparative research that was conducted in a quantitative approach. The random sampling method selected 126 elementary students (75 male and 51 female) aged 8.96 ± 1.50 years old. The kinematic data were collected by using kinematic video analysis in Kinovea 0.9.4 computer software. The independent variables were one leg standing position in second, distance per step (DPS) in centimeter, speed per step (SPS) in meter per second, step height (SH) in centimeter, kicking speed (KS) in meter per second, and estimated maximum distance (MD) in centimeter. All variables were measured both left and right foot. The data were analyzed using descriptive analysis and the Mann-Whitney U test to find the significant difference between gender. The results showed only two independent variables were significantly different. In hopping, there was left foot height (α= 0.044) and left foot speed (α= 0.043). In conclusion, elementary school students aged 8.96 ± 1.50 years old have a similar fundamental movement skill.

Keywords: Fundamental movements, Non-locomotor, Locomotor, Manipulative.

1. INTRODUCTION

Physical education uses physical activity to improve physical fitness and motor skills [1]. The physical education curriculum in elementary schools explains that physical education is an educational process that is systematically planned and utilizes physical activity aimed at improving individual quality neuromuscular, cognitive, social, and emotional [2]. Furthermore, it also plays a vital role in developing personality values through sports [3]. Physical education has three basic principles, i.e., (1) Fun physical education program is needed so that learning becomes effective, (2) The curriculum is necessary to provide skills development for students, (3) The curriculum needs to help create good health, physical activity, and physical fitness [4]. Elementary school students tend to imitate someone as a figure in their period of playing and learning [5]. Furthermore, it is essential to be implemented in the teaching strategies [6].

Fundamental movements are part of teaching objectives in the physical education curriculum for elementary school students. Basic movements consist of locomotor, non-locomotor, and manipulative motion [7].
Fundamental movements are essential before the students start the training in a specific sport skill [8]. The extraordinary ability of fundamental movements will allow the student to participate better in Sport or any physical activity [9]. Basic movements in certain sports, such as taekwondo is an effective way to improve posture [10]. Every child can reach the stage of gross motor development, especially when getting the proper stimulation [11]. However, in some special need conditions, the result could be deficient [12].

Basic locomotor motion is the behavior of moving the body from one place to another [13]. The locomotor motions are running, jumping, leaping, hopping, and others [9]. Locomotor motion is the basis for developing coordination of movements involving gross muscles, muscle growth, endurance, and stamina [14]. It could be trained together in rhythmic movement [15]. Non-locomotor motion is the ability to be balanced and stable [9]. The movement is carried out in place, i.e., static balance, static bend, static push, static pull, and others [16]. Manipulative skills are related to controlling the objects [17]. Manipulative motions are kicking, throwing, and hitting [9]. It can be improved by using specific sports skills and also traditional games [18].

One leg standing position with closed eyes is a test to determine a person's balance duration. According to Morioka et al. (2012), The balance ability begins to decline in the late 20s. Decreased plantar sensation appears to be associated with a reduced duration of standing on one leg. Furthermore, age and two-point plantar discrimination had a significant positive correlation, and two-point discrimination distance and time standing on one leg had a significant negative correlation.

Hopping is defined as jumping forward on one leg. According to Fukashiro et al. (1995), the Achilles tendon's peak mechanical strength and work in the calf muscles were 2233 N and 34 J in the squat jump, 1895 N and 27 J in the counter jump, and 3786 N and 51 J during hopping. Hopping is a gross motor skill that requires full-body vertical rigidity and control of horizontal movements, especially when trying to change jumping frequency [21]. Based on research data by Akay et al. (2006), hopping movements of the hind legs are not always associated with synchronous movements of the forelegs.

Running is a different movement from walking, especially in the absence of periods of double support. In the running, there are 2 phases, namely the stance and swing phase. According to Hamilton et al. (2008), the muscles involved in the running perspective are gastrocnemius soleus, quadriceps femoris, gluteus maximus, and hamstring at the ankles, knees hips, with the support of the toe muscles, namely m. flexor hallucis longus, flexor digitorum longus and intrinsic flexor. The short toes contract in response to ground pressure on the toes. In the propulsive phase, the contractions of these muscles are intensified. The toe flexor muscle contractions were more significant during the entire support phase when not wearing footwear Hamilton et al. (2008). In the pelvis, there are movements of flexion, lateral rotation (due to pelvic rotation), adduction (occurring early in the phase), and abduction at the end of the stage. These movements arise mainly when long strides are performed. It can also be caused by pelvic rotation Hamilton et al. (2008). The muscles involved in the swing phase are the tibialis anterior, extensor dithorium, longus, extensor hallucis longus, reflex action and momentum, hamstring, ilipoaso rectus femoris.

Players require passing and kicking skills to kick a moving ball, sent at a constant speed, towards one of four randomly determined targets [24]. The action in kicking occurs in the sagittal plane about the transverse axis and involves the hip, knee, and ankle joints. The hip bones involved are the femur and the pelvic girdle that form the ball and joint cavity. The knee bones involved are the femur and tibia, which include the hinge joint. The ankle bones involved are the tibia and calcaneus, which form the modified joint. Kicking consists of two phases, the preparation phase and the kicking phase [25].

Sports Biomechanics is the science that applies the laws of mechanics to living structures, especially the body's locomotor system. Biomechanics analysis provides quantitative and qualitative data to explain the human body movement mechanism [26]. The aims or sports biomechanics are (1) provide an evaluation of sports movements (techniques) so that they are carried out correctly, effectively, and efficiently [27]; (2) assessing aspects that could potentially cause injury; (3) assisting the recovery process for athletes who are injured; and (4) discuss externally generated forces that have the potential to affect athlete performance, such as gravity and frictional forces. The analysis of an athlete's performance can be implemented during a training session [28] or while participating in a championship [29].

Children have many unstructured physical activities and movements [30]. Sports biomechanics could analyze and improve the children's fundamental movement skills by using a detailed diagnostic and feedback on the movement skills which they performed. This study aimed to investigate the elementary school students' basic movement skills by using the kinematic approach. The basic movements in this research were correlated with lower body parts, i.e., one leg standing position with closed eyes (non-locomotor), hopping (locomotor), running (locomotor), and kicking (manipulative). There are two research questions in this study:
1. Are there any significant differences between male and female fundamental movement skills?
2. Are there any significant differences between right and left foot fundamental movement skills?

2. METHODS

2.1. Design and Sample

This study was conducted in a quantitative approach. The research design was approved by Universitas Negeri Surabaya Ethics Committee. There were 126 elementary students (75 male and 51 female) aged 8.96 ± 1.50 years old who participated in this study and were chosen as research samples using a random sampling method.

Table 1. Research samples descriptive analysis

| Gender     | Mean ± SD         | Age     | Weight (kg) | Height (cm) |
|------------|------------------|---------|-------------|-------------|
| Male (n=75)| 9.01 ± 1.05      | 9.13 ± 7.63 | 128.58 ± 5.76 |
| Female (n=51)| 8.88 ± 1.52    | 30.00 ± 6.11 | 127.45 ± 4.48 |
| Total (n=126)| 8.96 ± 1.50     | 29.48 ± 7.04 | 128.12 ± 5.29 |

2.2. Data Collection

The kinematic data were collected by using kinematic video analysis in Kinovea 0.9.4 computer software. The fundamental movement data were measured by kinematic analysis. The non-locomotor movement was one leg standing position with closed eyes in both left and right foot (figure 1). The measurement was using a timer (second). It started when the student was in the one leg standing position and ended when the student changed the pedestal position or dropped the other food due to losing balance.

The locomotor movements were hopping and running. The analysis was based on each step of those movements, both left and right foot (figure 2 and 3). The variables were distance per step (DPS) and speed per step (SPS). In addition, there was step height (SH) in hopping was also measured. The manipulative movements were kicking the ball both using left and right foot (figure 4). The analysis focused on kicking speed (KS) and maximum distance (MD), which were estimated using the projectile motion formula. The formula was Maximum Distance = (Vo² × sin 2θ) / g.

2.3. Data Analysis

The data were analyzed by using descriptive analysis in SPSS statistical software. Kolmogorov Smirnov normality test was applied to decide the further research.
Data measurements were presented in mean and standard deviation ($\bar{x} \pm SD$). The significance level was set at $\alpha < 0.05$, and all tests were two-tailed.

### 3. RESULTS AND DISCUSSIONS

Based on the normality test by Kolmogorov Smirnov, the data were not in the normal distribution. Furthermore, the Mann-Whitney U test was performed to find the significant difference between gender (Table 2). The results showed hopping height ($\alpha = 0.044$) and hopping speed ($\alpha = 0.043$) in the left foot were significantly different.

**Table 2. Mann Whitney U test**

|                      | FMS                                      | Male (n=75) | Female (n=51) | Total (n=126) | Sig.     |
|----------------------|------------------------------------------|-------------|---------------|---------------|----------|
| Non-locomotor movement (One Leg Standing Position) | Right foot balance                        | 3.81 ± 1.17 | 4.07 ± 1.09  | 3.92 ± 1.14  | 0.229    |
|                      | Left foot balance                         | 3.97 ± 1.25 | 3.91 ± 1.08  | 3.94 ± 1.18  | 0.676    |
| Locomotor movement (Hopping) | Right foot distance                        | 114.53 ± 22.88 | 117.26 ± 20.76 | 115.64 ± 22.01 | 0.386    |
|                      | Right foot height                         | 51.93 ± 8.31 | 51.96 ± 6.38 | 51.94 ± 7.57 | 0.952    |
|                      | Right foot speed                          | 3.60 ± 0.44 | 3.62 ± 0.33  | 3.61 ± 0.40  | 0.435    |
|                      | Left foot distance                         | 117.37 ± 19.92 | 109.97 ± 23.38 | 114.38 ± 21.61 | 0.062    |
|                      | Left foot height                          | 52.17 ± 7.59 | 49.77 ± 7.04 | 51.04 ± 7.47 | 0.044*   |
|                      | Left foot speed                           | 3.57 ± 0.36 | 3.67 ± 0.41  | 3.61 ± 0.38  | 0.043*   |
| Locomotor movement (Running) | Right foot distance                        | 79.26 ± 10.33 | 78.07 ± 8.91 | 78.78 ± 9.76 | 0.612    |
|                      | Right foot speed                          | 4.92 ± 0.73 | 4.87 ± 0.54  | 4.90 ± 0.66  | 0.852    |
|                      | Left foot distance                         | 80.31 ± 11.14 | 76.56 ± 8.71 | 78.79 ± 10.35 | 0.082    |
|                      | Left foot speed                           | 4.93 ± 0.67 | 4.83 ± 0.59  | 4.88 ± 0.64  | 0.665    |
| Manipulative movement (Kicking) | Right foot kicking speed                  | 19.68 ± 4.40 | 19.14 ± 3.58 | 19.46 ± 4.08 | 0.756    |
|                      | Right foot kicking distance                | 18.79 ± 5.45 | 20.19 ± 5.34 | 19.36 ± 5.42 | 0.093    |
|                      | Left foot kicking speed                   | 19.54 ± 3.69 | 19.21 ± 3.70 | 19.41 ± 3.69 | 0.680    |
|                      | Left foot kicking distance                 | 18.76 ± 6.14 | 19.85 ± 4.97 | 19.20 ± 5.70 | 0.432    |

**Notes:**
- * Significant < 0.05

The development of fundamental movement skills, both right and left foot are well balanced. It is possibly caused by the appropriate activity, which could stimulate both sides of the foot to move equally. Furthermore, inappropriate support and stimulus of motoric could reduce motor coordination [35]. Training activity could be conducted to enhance the mastery of fundamental movement skills [36]. Parents’ roles are essential to support the fundamental movement skill [37]. Children with good basic movement skills could perform better and enjoy participating in physical activity or Sport [34].

### 4. CONCLUSION

There were significant differences between male and female FMS, particularly on the hopping left foot height and speed. However, there were no significant differences between right and left foot FMS. Future research could be conducted in a larger society to inquire about the FMS, particularly in elementary school students.

Wilcoxon's two related sample tests were also implemented to analyze the significant difference between left and right foot (table 3). There were no significant differences between left and right foot in all of the fundamental movements' skills.

**Table 3. Wilcoxon two related sample tests**

|                      | Mean ± SD | Sig.     |
|----------------------|-----------|----------|
| Non-locomotor movement (One Leg Standing Position) | Right foot balance | 3.92 ± 1.14 | 0.825 |
|                      | Left foot balance | 3.94 ± 1.18 |
| Locomotor movement (Hopping) | Right foot distance | 115.64 ± 22.01 | 0.534 |
|                      | Left foot distance | 114.38 ± 21.61 |
|                      | Right foot height | 51.94 ± 7.57 | 0.213 |
|                      | Left foot height | 51.04 ± 7.47 |
|                      | Right foot speed | 3.61 ± 0.40 | 0.469 |
|                      | Left foot speed | 3.61 ± 0.38 |
| Locomotor movement (Running) | Right foot distance | 78.78 ± 9.76 | 0.972 |
|                      | Right foot speed | 78.79 ± 10.35 |
|                      | Left foot distance | 4.90 ± 0.66 |
|                      | Left foot speed | 4.88 ± 0.64 |
| Manipulative movement (Kicking) | Right foot kicking speed | 19.46 ± 4.08 | 0.941 |
|                      | Left foot kicking speed | 19.41 ± 3.69 |
|                      | Right foot kicking distance | 19.36 ± 5.42 |
|                      | Left foot kicking distance | 19.20 ± 5.70 |

**Notes:**
- * Significant < 0.05
ACKNOWLEDGMENTS

The research was funded by Universitas Negeri Surabaya in Research Competition Scheme 2021.

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