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DETERMINE FOOTWORK AND INTENSITY BY USING WIRELESS ACCELEROMETER AND GYRO

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SUMMARY
The purpose of this study was to investigate the features of different footwork (walk, run and jump in different intensities) by accelerometer and gyro. The features of footwork are determined by observing the characteristic of digital signal. Fifteen healthy male college students were recruited in this study. A self-made wireless inertial measurement unit (200 Hz) was attached to the participant's left foot to observe the features of different footwork. One-way repeated measures ANOVA was used to determine the difference among axes. Paired t-test was used to determine the difference between intensities. The significant level was set at $\alpha = .05$. The range of acceleration change in anteroposterior axis is significantly larger than other two axes. The range of angular velocity change in frontal axis is significantly larger than other two axes. We can observe that each footwork has its own special pattern in angular velocity (frontal axis). Therefore, combining accelerometer and gyro is capable of determining different footwork (walk, run and jump). And the intensity can be determined by the range of acceleration change in anteroposterior axis.

INTRODUCTION
As the improvement of technology and Micro Electro Mechanical System (MEMS), digital sensor becomes lighter, smaller, and cheaper which has been wildly used in research, clinical, and even sports and exercise [1]. Sensors like accelerometer or gyro can detect the change occurred by body movements [2-4]. In research area, digital sensors were used to recognize household activity, gait analysis, or diagnose patient physical ability. In the market of sport and exercise, more products with sensor were developed to provide more information to the users.

The products that using digital sensors like Nike+ fuelband and Adidas miCoach can provide the information like running speed, step frequency, exercise time, and training intensity. However, there is still a lot of information about movement which current systems can not provide. Therefore, the purpose of this study was to investigate the features of the different footwork (walk, run and jump) by accelerometer and gyro.

METHODS
Participants
Data collection was performed on a group of 15 health males. The volunteers were 26.9 ± 3.1(mean, SD) years old, 173.5 ± 5.4 cm height, and 73.4 ± 9.0 kg. All participants were with none serious lower extremity injury in last 6 months.

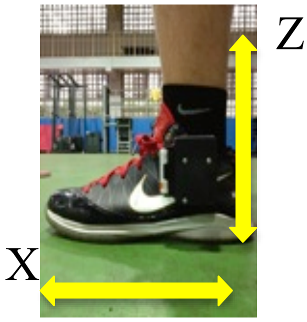

Figure 1: The axes of the IMU

Devices
The inertial measurement unit used in this study included a tri-axis accelerometer (ADXL345) and a tri-axis gyro (mpu3050). The sampling rate was 200 Hz. The sensor was set on the lateral side of the left foot (fig. 1). A treadmill was used to control the walking and running speed.

Movement
In this study, the participants were asked to do three different movements with two different intensities. The movements included slow walk (1.0 m/s), fast walk (2.0 m/s), slow run (2.0 m/s), fast run (3.5m/s), low jump and high jump. The walk and run were preforming on a treadmill, and jump were preforming on level ground.

Data processing & analysis
Low pass filter (10 Hz) was applied to all the accelerometer and gyro data. The range of acceleration change in three axes, and the peak angular velocity in 3 different movements were calculated. We also observed the pattern of angular velocity to find out differences among different movements.

Repeated measures ANOVA were used to determine the difference among different axes. Paired t-test was used to determine the difference between the different intensities. The significant level was set at $\alpha = .05$.

RESULTS AND DISCUSSION
The ranges of acceleration change are shown in table 1. The anteroposterior (axis x) shows the largest change of acceleration in all movements, even in jumping. This result may be caused by the plantar-flexion movement while take off and landing.

The ranges of angular velocity change are shown in table 2. The plantar/dorsiflexion (axis y) shows the largest change of angular velocity in all movements, and there are significant differences among different intensities as well as different movements. This result may be caused by the anatomy structure of ankle joint, and the plantar/dorsiflexion are the major movement axis of this three activities.

Table 1: The range of acceleration change

	anteroposterior (x)	mediolateral (y)	vertical (z)
Slow walk	$4.27\pm0.50^{ab\#}$	$1.40\pm0.48^{b\#}$	$2.40\pm0.36^{a\#}$
Fast walk	$7.68\pm0.85^{ab\#*}$	$2.27\pm0.70^{b\#}$	$3.55\pm0.47^{a\#*}$
Slow run	$6.24\pm0.89^{ab\#*}$	$2.10\pm0.64^{b\#}$	$2.85\pm0.53^{a\#*}$
Fast run	$9.86\pm1.06^{ab\#}$	$3.06\pm0.89^{b\#}$	$5.29\pm0.74^{a\#}$
Low jump	$3.78\pm0.81^{ab\#}$	$1.55\pm0.63^{b\#}$	4.89 ± 0.64^{a}
High jump	$7.25\pm1.77^{ab\#}$	$3.04\pm1.08^{b\#}$	5.18 ± 0.96^{a}

[a] p<.05 compared with y axis. [b] p<.05 compared with z axis. [#] p<.05 compared with different intensities in same movement. [*] p<.05 compared with different movement in same intensity.

Table 2: The range of angular velocity change (degree/sec)

	eversion/inversion (x)	plantar/dorsiflexion (y)	abduction/adduction (z)
Slow walk	$220.35\pm31.80^{ab\#}$	$776.31\pm52.67^{b\#}$	$267.89\pm84.03^{a\#}$
Fast walk	$253.25\pm35.48^{ab\#}$	$1139.67\pm75.18^{b\#*}$	$378.62\pm102.74^{a\#*}$
Slow run	$271.21\pm68.17^{ab\#}$	$817.53\pm64.19^{b\#*}$	$474.72\pm95.31^{a\#*}$
Fast run	$403.58\pm83.54^{ab\#}$	$1258.28\pm78.95^{b\#}$	$616.55\pm122.18^{a\#}$
Low jump	$228.82\pm83.56^{a\#}$	$884.61\pm72.80^{b\#}$	$248.79\pm64.42^{a\#}$
High jump	$504.83\pm261.23^{a\#}$	$961.59\pm123.90^{b\#}$	$553.61\pm152.76^{a\#}$

[a] p<.05 compared with y axis. [b] p<.05 compared with z axis. [#] p<.05 compared with different intensities in same movement. [*] p<.05 compared with different movement in same intensity.

Peak acceleration and angular velocity were used to recognize movement [5]. We found that the signal curve of angular velocity change in plantar/dorsiflexion shows a regular pattern in walking, running, and jumping (Fig. 2).

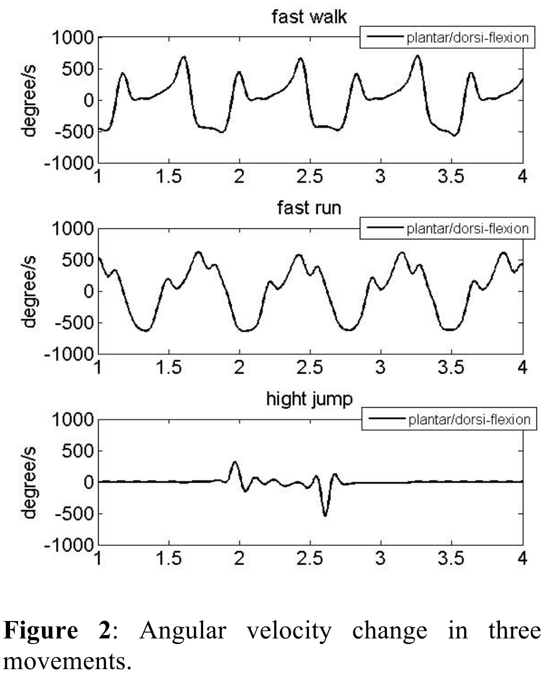

Figure 2: Angular velocity change in three different movements.

CONCLUSIONS

According to the results, we found that the accelerometer combined with gyro can be used to recognize the basic movements like walking, running, and jumping. The intensity of movement can be determined by the range of acceleration change. Future research should put more attention on comprehensive movements like different sports or focus on the change in lateral direction.

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