

Development of Back Extensor Muscle Strength Estimation Formula using EMG and IMU sensors

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Introduction

Back extensor strength (BES) is age-sensitive indicator and predictor of physical performance, frailty and osteoporosis. However, an appropriate method to assess BES has not yet been described. To this end, in this study, the estimated BES using electromyography (EMG) and inertial measurement unit (IMU) sensors and the BES measured by the hand-held dynamometer (HHD) were compared. As a task in the first year of a three-year study to find out the relationship between osteoporosis and back extension strength, we tried to find a method for measuring BES using EMG and IMU sensors and to develop an estimation equation.

Methods

BES test and functional evaluation were performed on 55 adult women aged 19 years or older. BES test using HHD was measured by fixing it with the Tripod & Belt system device in the prone position, and lifting the upper body with maximum effort. BES tests using EMG and IMU sensor were performed while performing 1 set of back extension exercises with EMG attached to the L1 level and IMU sensor attached to the interscapular area. Exercise consisted of lifting the upper body from a prone position, holding for 5 seconds, resting for 10 seconds for 10 repetitions (Figure 1).

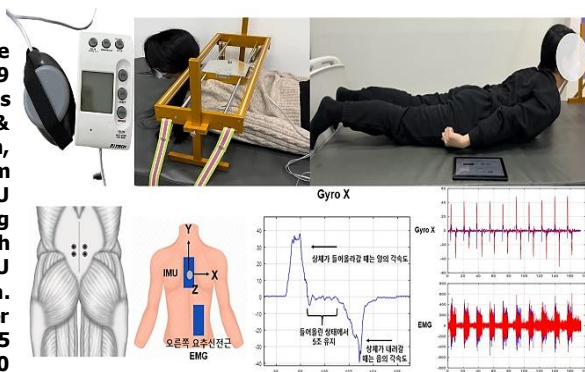


Fig 1. BES test using EMG and IMU sensor

Results

Baseline characteristics were presented in Table 1. A BES estimation equation was developed through multiple linear regression analysis. A system was constructed to estimate the BES measured by HHD through the EMG and IMU signals acquired during back extension exercise (Figure 2). Quantified parameters were extracted from the EMG and IMU signals, and only parameters highly correlated with the BES were extracted to obtain a multiple linear regression equation.

A total of 3 models were developed, which used muscle strength/BMI, muscle strength/weight, and muscle strength/height². It was confirmed that the estimated BES index well estimated the BES measured by HHD. Among the three BES estimated indices, muscle strength/BMI ($r=0.783$, $p<0.001$) showed the highest correlation between measured and estimated values.

Table 1. Participants characteristics

	Mean	SD
Age (y)	24.29	3.20
Height (cm)	161.82	5.37
Weight (kg)	56.68	7.95
BMI (kg/m ²)	21.70	3.36
HHD_max (N)	120.75	34.89
HHD_mean (N)	105.78	29.94
HHD_RMS_max	141.76	76.96
HHD_RMS_mean	123.24	66.87
Exercise RMS_max	121.01	75.71
Exercise RMS_mean	91.50	46.13
Right HGS (kg)	26.45	4.11
Left HGS (kg)	24.71	3.69
FTSST (s)	6.09	1.23
30s SST	24.75	5.71
SMI (kg/m ²)	6.85	0.75

HHD; hand-held dynamometer, RMS; root mean square, HGS; handgrip strength, FTSST; five-times sit-to-stand test, 30s SST; 30 secs sit-to-stand test, SMI; skeletal muscle index

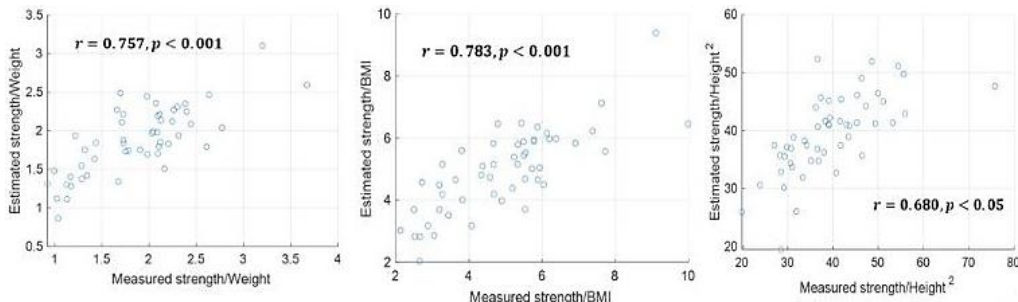


Fig 2. Distribution of the measured BES index and estimated BES index

Conclusion

BES measurement method and estimation equation using EMG and IMU sensors have reliability compared to the BES estimated by HHD and could be an easier way to evaluate BES.