Automating Threshold Calibration for EMG-based Exergaming

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Introduction: With the growing prevalence of cardiometabolic disorders, mobile technology is being leveraged for fitness tracking and encouraging a more active lifestyle. Individuals who use wheelchairs due to lower limb mobility impairment face common barriers such as transportation, finding accessible gym equipment, and access to physical therapy. To assist those individuals in overcoming such barriers, our lab has been developing a mobile fitness application (WOW-mobile), capable of communicating with wireless sensors to track physical activity levels as well as drive the game engine of three different "exergames" tailored for exercising in wheelchairs in the convenience of the user's own home. The current version of the app provides entertaining acti-vities to gamify exercises, trend tracking, and social networking through cloud-based multiplayer features and leaderboard. However, there are a number of limitations on user friendliness, one of the major ones being the need for a tedious process of setting thresholds upon each session due to variability from session to session in precise electrode location, noise sources, and in level of user's muscle conditioning. Here, we perform linear regression modeling of the thresholds based on anthropometric data in order to automate the threshold calibration process.

Methods: Ten subjects performed exercises on our WOW-mobile app while wearing the following sensors: a Flexdot electromyography (EMG) sensor (Dynofit, Inc.) on the bicep and anterior deltoid of the subject's dominant arm and a wrist-worn heart rate monitor (Alpha, MioGlobal, Inc.). Repetitions of three exercises were performed with increasing intensity until maximum heart rate was reached: air boxing (punching), bicep curls and military press using elastic resistance arm bands. The mobile app stored the sensor data on a cloud server. The data was downloaded and imported into Matlab for offline analysis. A Matlab script was written to determine the EMG threshold to detect muscle contractions using a percentage of the maximum voluntary contraction. Then, the thresholds were adjusted manually to achieve the most accurate detection possible. These upper and lower threshold for each game for each of the two muscles were regressed against the following anthropometric and physiological variables: age, height, weight, max heart rate, and maximum voluntary contraction. Multiple linear regression was carried out using Matlab's *regress* function, and the coefficient of determination (R^2) values were computed as a measure of the goodness of fit.

Results and Discussion: Table 1 provides the R^2 values for the upper and lower threshold for each game and each muscle. Multiple linear regression performed well and the linear model depended most heavily on the individual's height, maximum heart rate, and age. Figure 1 illustrates the performance of EMG contraction detection using the thresholds obtained by our automated process.

Table 1. Goodness of fit metrics (R^2) for the multiple linear regression model regressing EMG thresholds vs anthropometric and physiological variables.

R^2 Values				
	Ant-Delt		Bicep	
	UT	LT	UT	LT
Punches	0.68	0.73	0.61	0.38
Bicep Curls	0.97	0.99	0.55	0.75
Military Press	0.67	1	0.75	0.69

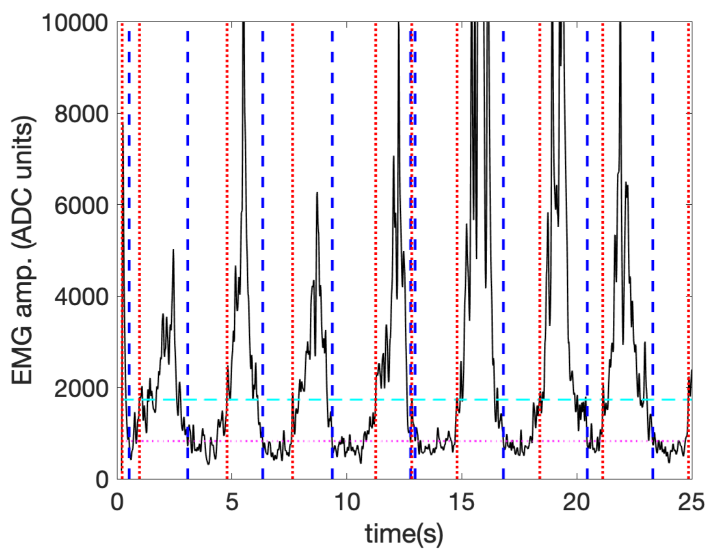

Figure 1. Example showing the EMG from one participant (solid) with the starts (vertical dashed blue lines) and ends (vertical dotted red lines) of the detected contractions based on automatically determined thresholds.

Conclusions: Multiple linear regression based on user height, weight, age, maximum heart rate, and can be used to automatically set user thresholds for EMG-based exergaming to make for a more user friendly mobile exergaming experience.