EFFECT ON RESULTING MAXIUMUM ACCELERATION OF THE SHOULDER JOINT BY COMPARING PLYOMETRIC AND DYNAMIC PUSH-UPS

D. Höftberger[1], A. Kozek[1], J. Langer[1], J. Obergruber[1]

[1] Fachhochschule Technikum Wien, Wien, AUT

1 Abstract

Erstellen sie eine Kurzfassung, die etwa 300 Worte umfasst. Zur klaren Trennung der Kurzfassung vom restlichen Text ist die Kurzfassung kursiv zu setzen – font size 11, Times New Roman. Vermeiden sie Absätze im Abstract. Bitte folgen sie in ihrem Artikel den vorgeschriebenen Schriftarten (font) und Schriftgrößen (font size). Danke.

2 Introduction

Push-ups are probably one of the oldest and simplest muscle train methods for the upper body. A regular push-up is performed in a prone position by raising and lowering the body using the arms.

This kind of workout does not require any external weights. The athlete’s own weight is enough for a serious strength endurance workout (except high trained elite athletes).

While this exercise primarily targets anterior and medial deltoids, triceps brachii, pectoralis major and pectoralis minor, support from other muscles is required and results in a wider range of integrated muscles. Those secondary integrated muscles are mainly rhomboid major and rhomboid minor, posterior deltoids, serratus anterior, rectus abdominus, gluteus maximus, and quadriceps femoris.

The aim of the Laboratory exercise of December 6th at the Sports Engineering Laboratory at the FH Technikum Vienna, was to measure the maximal acceleration of the shoulder, while doing push ups. The main focus was on the comparison between a plyometric push up (explosion force) and dynamic push up. The test person (22 years old, endurance athlete) had to accomplish one plyometric push up (pushing up from the lowest push up position (Fig.1)) and three dynamic push ups, where the second one was relevant for measurement.

The hypothesis was that the acceleration at the plyometric push up is higher

3 Methods

One physically healthy male student was the subject (S1) of this investigation. S1 was 22 years old, 178 cm tall and had a weight of 68 kg. He was right hand dominated and exercising endurance sports on a competitive basis. Furthermore S1 was free of upper-extremity disorders. S1 was wearing body-tight clothes to minimize falsifications due to cloth slipping.

For recording of data S1 was equipped with a 3-axis MEMS (micro-electromechanical system) accelerometer basing on capacitive g-sensing technology. The MMA7260QT (Freescale Semiconductor Inc., Muenchen, Germany) provides a 4-step selectable sensitivity value and a maximum measuring range of 6g`s in every axis. The accelerometer was attached to the subjects left shoulder joint in the area of caput humeri via a Velcro fastening strip (orientation of the sensor refers to FigX). As only the value of the resulting total acceleration was of interest for this investigation the sign of the single components (X, Y, Z) and thus also the resulting total direction was disregarded. The resulting total acceleration in a 3D vector system was calculated according to equation (**Fehler! Verweisquelle konnte nicht gefunden werden.**)

$$a_{res} = \sqrt{{a_x}^2 + {a_y}^2 + {a_z}^2} \qquad (1)$$

Additionally a tilt sensor was fitted to the subject’s back in the area of thoracic vertebra TH5 in order to get information about the attitude of the subject`s sagittal plane in relation to the ground surface. The measured angle is defined by the plane of the ground surface and the longitudinal axis of the subject’s body (Fig. 1**Fehler! Verweisquelle konnte nicht gefunden werden.**). The aim was to use this information for chopping a DYN pushup set into three single pushup moves (lowest position of subject during exercise as starting point for the following pushup cycle). The used tilt sensor CXTA02 (MEMSIC Inc., San Jose, California), also one of MEMS style, provided a linear voltage/tilt-angle characteristic within a range of +/-20° and a full measuring range of +/-75°. A maximum band of 30° during motion was expected causing a sensor output range of 2.5 to 3.5V under consideration of the sensors sensitivity.

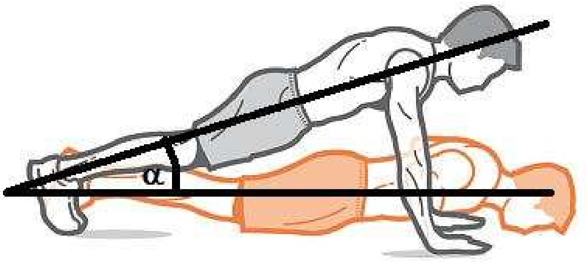


Fig. 1: schematic design of measured angle during pushup exercise

Both sensors, the accelerometer as well as the tilt sensor, were connected to analog inputs (voltage measuring) of a 11-bit (for single-ended wiring) A/D-converter according to the wiring diagram in Fig. 2. The NI USB-6008 (National Instruments Corp., Austin, Texas) is connected to a PC via a USB interface and can be responded using LabView (National Instruments Corp., Austin, Texas). It provides up to eight analog inputs, two analog outputs and eight digital inputs. While it was possible to use the onboard power supply (+2.5/+5V) of the USB-6008 for the accelerometer (2.2 to 3.6V) the tilt sensor (6 to 30V) had to be supplied separately using a regulated lab power supply (type PS2032-025, EA Elektro-Automatik GmbH&CoKg, Viersen, Germany).

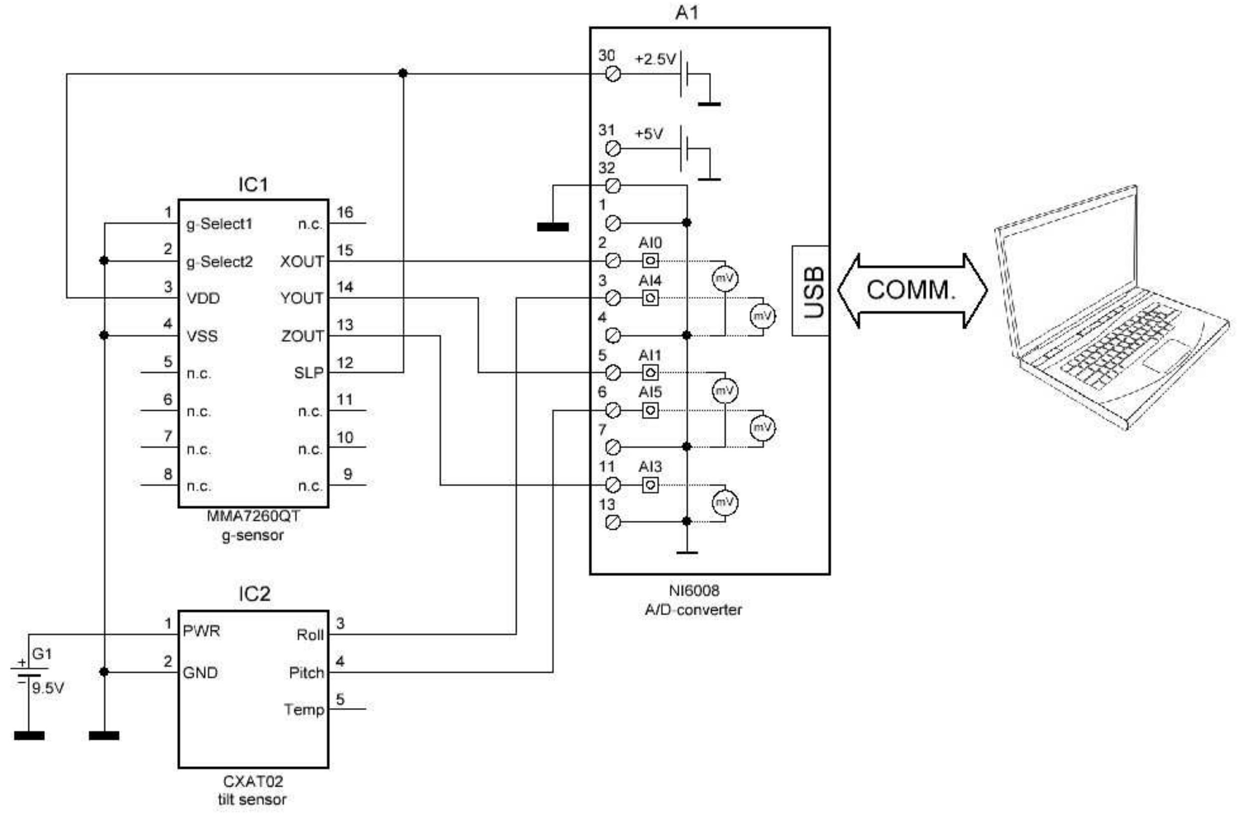


Fig. 2: wiring diagram of the measurement set-up

S1 was asked to perform a series of 5 sets of DYN and PLY pushups following the procedure shown in Tab. 1. The final amount of 15 pushups (5 sets per 3 pushups) concerning the DYN series and 5 pushups for the PLY series were intended to create a reliable arithmetic mean (AM) and standard deviation (SD) for the acceleration maxima of each single DYN and PLY pushup act.

series	sets	recovery time between sets
DYN	5x 3 pushups	1 min
recovery time of 5 minutes		
PLY	5x 1 pushup	1 min

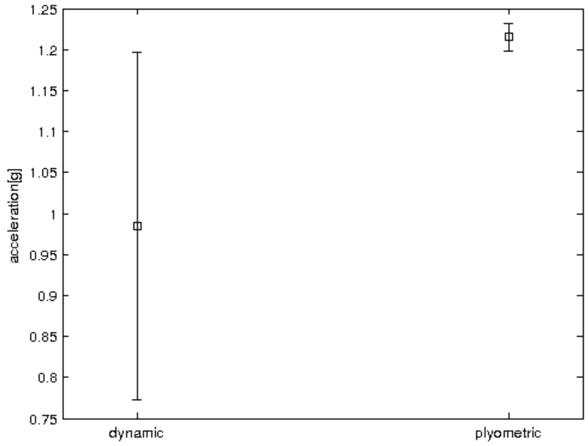
Tab. 1: execution procedure of accomplished pushup series

Due to software delay times S1 was tasked to start his exercises not before the LabView chart connected to the output of the DAQ-tool displayed the sensor output signals. Data was recorded at a refresh rate of 1000Hz in continuous sampling mode. Additional Data-handling was managed in

LabView by writing the recorded data into an output-file which was further processed with MatLab routines (The Mathworks Inc., Natick, MA, USA). From all gathered data series for each single pushup exercise the maximum 3D-acceleration value is determined (using equation (1)) and from these maxima (15 for DYN series and 5 for PLY series) an AM and SD for each pushup style (DYN and PLY) is created.

4 Results

All measured values are linear and resulting accelerations because of a three dimensional acceleration sensor. For each case, PLY and DYN pushups, five sets were recorded. Acceleration values are shown in relation to the earth gravity acceleration (g = 9.81 m/s^2) and also in SI-units (m/s^2). The maximum occurring acceleration of the PLY pushup was in average 24,4% higher than during the DYN pushups (Tab. 2). Hence the standard deviation of the maximum occurring acceleration of all samples is in the dynamic case twelve times higher than in the PLY case (Fig. 3).



	PLY	DYN
average acceleration [g]	1,22	0,98
average acceleration [m/s^2]	11,97	9,61
standard deviation [m/s^2]	0,167	2,060

Tab. 2: maximum occurring accelerations (resulting and total) values during PLY and DYN pushups in comparison (mean values).

Fig. 3: visual comparison of mean values of maximum occurring accelerations [g] of PLY (right) and DYN pushups (left) including their standard deviations.

5 Discussion

The hypothesis that it is possible to reach a higher resulting, total acceleration during a PLY pushup compared to DYN pushups can be verified. However to interpret the results properly some aspects have to be considered. First it was not possible to determine the position of the body when the maximum acceleration occurred. Secondly it was not possible to determine the direction of the maximum acceleration in the absence of a reference coordinate system. This is especially important for dynamic pushups where up- and downward acceleration peaks occur. To solve both problems a tilt sensor was used to record the BTA during push-ups. However the function of the available tilt sensor was presumably not designed for such high accelerations or high alternation rates. The graph of the BTA in relation the floor did not show any usable values for marking out significant upper body positions of the subject during pushup cycles (Fig. 4). Furthermore it was thus impossible to split the DYN pushup cycle into the three single pushup-movements of which it consisted. This resulted in a reduction of pushup cycle amounts which would have been necessary for DYN AM and SD values from 15 to 5.

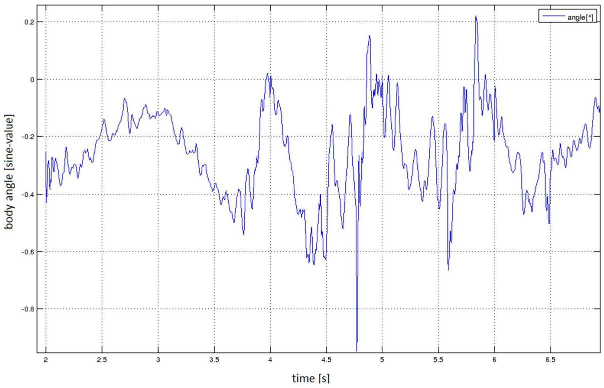


Fig. 4: example graph of BTA behavior during DYN pushup set (without any usable benefit for application requirements)

In addition the reason for the twelve times higher standard deviation of the maximum acceleration during dynamic pushups compared to plyometric is that the level of expenditure increases much higher when exercised dynamic. If the breaks between dynamic pushup sets would be long enough to do a full recovery, the standard deviation could be decreased.