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VALIDATION OF A INERTIAL MOVEMENT UNIT WITH A LINEAR ENCODER TO EVALUATE STRENGTH AND POWER

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ABSTRACT

The object of this study was to find out the evaluation and reliability of an inertial movement unit (IMU), based on the TITAN (rO2 Sport Technology and Consulting, Valencia, Spain) system, measuring the variables of sports performance. A linear encoder T-Force (Ergotech System, Murcia, Spain) was used to compare data obtained. 10 voluntary subjects with previous experience of strength training in the study participated. They carried out a total of 200 times bench press in concentric phase, 50% and 70% of individual body weight. The variables analyzed were: maximum speed, maximum acceleration, maximum strength and maximum power peak. Models of linear regression with an independent variable (T-Force data) and a dependant variable (TITAN data) were applied. The assumed independence of error was contrasted by way of a Durban-Watson trial. Partial self correlations were calculated with a significant level $p \leq 0.05$. The existence of interclass correlations between the averages of both apparatus, ranging between 0.95 and 0.99 was conformed. In conclusion, the TITAN system could be a valid system to measure maximum velocity, maximum acceleration, maximum strength and maximum power peak during the bench press trial. Therefore, this system based on IMU, could be a valuable tool for the evaluation of strength and power training in the execution of this movement.

Keywords: IMU, strength, power, bench press

VALIDACIÓN DE UNA UNIDAD DE MOVIMIENTO INERCIAL CON UN CODIFICADOR LINEAL PARA EVALUAR FUERZA Y POTENCIA

RESUMEN

El objetivo de este estudio fue descubrir la evaluación y la confiabilidad de una unidad de movimiento inercial (IMU), basada en el sistema TITAN (rO2 Sport Technology and Consulting, Valencia, España), que mide las variables del rendimiento deportivo. Se utilizó un codificador lineal T-Force (Sistema Ergotech, Murcia, España) para comparar los datos obtenidos. Participaron 10 sujetos voluntarios con experiencia previa en entrenamiento de fuerza en el estudio. Realizaron un total de 200 veces press de banca en fase concéntrica, 50% y 70% del peso corporal individual. Las variables analizadas fueron: velocidad máxima, aceleración máxima, fuerza máxima y pico de potencia máxima. Se aplicaron modelos de regresión lineal con una variable independiente (datos de T-Force) y una variable dependiente (datos de TITAN). La supuesta independencia del error fue contrastada mediante un juicio de Durban-Watson. Las auto correlaciones parciales se calcularon con un nivel significativo $p \leqslant 0.05$. Se confirmó la existencia de correlaciones entre clases entre los promedios de ambos aparatos, que oscilaban entre 0,95 y 0,99. En conclusión, el sistema TITAN podría ser un sistema válido para medir la velocidad máxima, la aceleración máxima, la fuerza máxima y el pico de potencia máxima durante la prueba de press de banca. Por lo tanto, este sistema basado en IMU, podría ser una herramienta valiosa para la evaluación del entrenamiento de fuerza y potencia en la ejecución de este movimiento.

Palabras clave: IMU, fuerza, potencia, press de banca

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INTRODUCTION

The technological evolution takes us to the use of portable microsensors, for the quantification of sports movement. Currently, the accelerometry from the industrial world is used for objectively measuring the kinematic parameters of physical activity (18, 21).

The methods used until the moment on the analysis of sport movement have been limited to use inside the laboratory (10, 17). The need to carry out measurements on training and competition grounds has driven sports scientists to implement themselves with industrial engineering, in order to develop new Wireless network technologies, more economically than those carried out in laboratories (3, 4, 6, 7, 16, 20).

The inertial movement units (IMU) have the capacity of carrying out a tridimensional evaluation (3D) of human movements (9, 15), allowing, therefore, real sports action evaluation.

Our object was to check the evaluation and reliability of an IMU, based on the TITAN (rO2 Sport Technology and Consulting, Valencia, Spain) system by comparison of data obtained in simultaneous performances with a linear encoder as a linear positional measurement (LPM T-Force) to measure performance variables (maximum speed, maximum acceleration, maximum strength and maximum peak power).

METHOD

Experimental approach to the problem

In order to study evaluation and reliability of an IMU, bench press was selected as the movement to analyse, and a linear encoder, such as *gold standard.*

In an approximation to our study (2) a high correlation as regards 1RM, by way of speeds obtained in a press bench protocol, using a linear encoder (Musclelab, Ergotest, Norway) we selected the linear encoder (T Force System, Ergotech, Murcia, Spain) for habitual use in training measurement and control with additional loads since they were being used for: Establishing the importance of kinematic parameters in the measurement of strength during the propulsive phase of the movement to different intensities of 1RM (19) and estimate the load intensity by way of movement speed during the bench press exercise (11).

Participants

10 subjects (31.5 ± 5.01 years, 175.56 ± 5.75 cm, 77.86 ± 9.65 kg) with previous experience in strength training (6 ± 3.83 years) participated in the study.

All participants gave their consent for the voluntary participation in the study, giving details of the objective and nature of each trial, the associated risks and the expected benefits, assuring them the confidentiality of the process.

None of the subjects carried a pathology injury which would have incapacitated them from carry out the trial. The participation was anonymous and consent was given for data treatment, which were strictly scientific, according to legal rules (Law 15/1999 Personal Data Protection). This investigation was approved by the Ethics Committee of the University of Valencia registered with number H1437129471019, following the ethical principles described at the Declaration of Helsinki (5).

Procedure

The tests were carried out in laboratory with constant controlled atmospheric variables (absolute atmospheric pressure: 1013 hPa, relative humidity 65%; height: 46m. above sea level and temperature of 18 °C). The tests consisted in performing the bench press movement from the supine position on the bench in vertical concentric action facing up in a guided manner and with the intention of achieving maximum speed (2, 13, 19). Each subject did 2 series of 10 repetitions: the first series at 50% and the second series at 70% of the individual body mass, respectively, with 3 minutes recuperation between series. Previously, before finishing the series, the subjects carried out a standard specific warm up of the muscle groups implicated in the study, which consisted of: superior member joint mobility (shoulders, elbows and wrists), isometric board face downwards 20 seconds and 10 arm push ups. Both comparative objective gadgets were placed in the Olympic Bar in the same place.

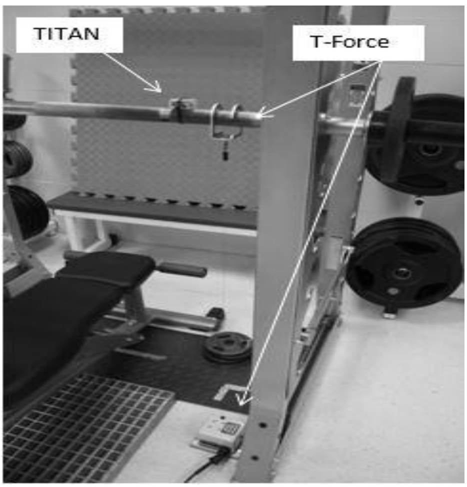

FIGURE 1: Disposition of measurement systems.

Statistical analyses

The analysis data was performed on SPSS statistical software package (version 22.0; SPSS, Inc., Chicago, IL, USA). Least Square Linear Regression models with an independent variable (T-Force data) and a dependant model (TITAN data) were applied. The supposed independency of errors contrasted in all cases through the trial Durbin-Watson, owing to its effect on inflation of the error type, measuring the grade of autocorrelation between the corresponding residues upon each observation and the previous one. Calculations were performed for the autocorrelations in each situation, considering just one series formed from the measurements of both apparatus and a delay equal to the number of trials carried out.

Mean (M), Standard Deviation (SD), and Coefficient of Variation (CV) were obtained for each system on each measurement, Maximum Velocity (Vmax), Maximum Acceleration (Amax), Maximum Force (Fmax) and Maximum Power Peak (Pmax), for the first (50%) and second (70%) series.

The Coefficient of Determination (R2) was obtained for measuring the proportion of the variance in the dependent variable that is explained from the independent variable. The Pearson's Correlation Coefficient (PCC) was used to examine the linear dependence between these two variables. A Confidence Interval was also obtained for better estimation. The Intraclass Correlation Coefficient (ICC) was obtained for measuring the reliability of the different measurements. The Coefficient of Variation (CV) was obtained for each system. All such statistics were obtained for Velocity, Acceleration, Force, and Power Peak. Magnitude of effect within exercises was estimated with Cohen's effect size (ES) for a quantitative measurement of the strength of the correlation in the sample. All tests were conducted with a criterion level for significance (p-value) less or equal than 0.05.

RESULTS

Figures 2, 3, 4 and 5 show linear regressions on each variable, including results obtained in the two series of the 10 subjects.

The 4 variables obtain high correlations and are very similar, being able to link them in pairs of evaluation proximity. Situating Maximum Acceleration and Maximum Force with PCC ranging in the interval [0.9907,0.975]. In the same way, correlations of Maximum Velocity and Maximum Power Peak ranging in the interval [0.9559, 0.9109].

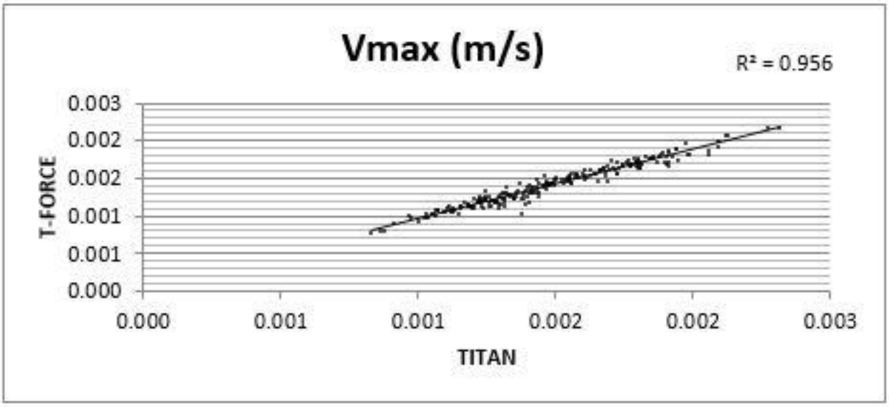

FIGURE 2: Descriptive Statistic. Linear Regression. Maximum Velocity (Vmax).

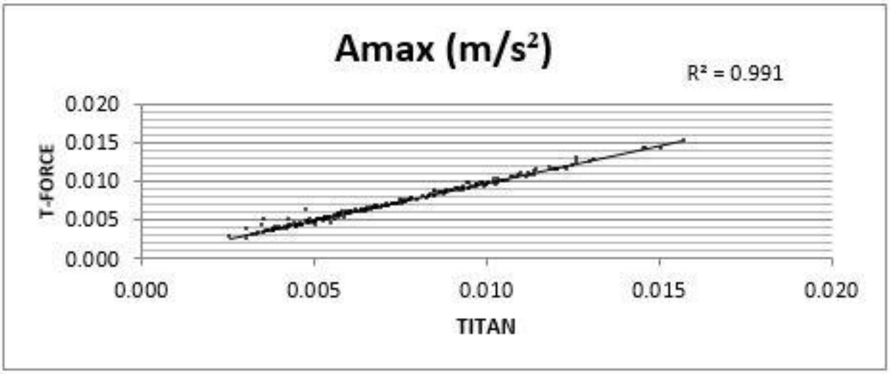

FIGURE 3: Descriptive Statistic. Linear Regression. Maximum Acceleration (Amax).

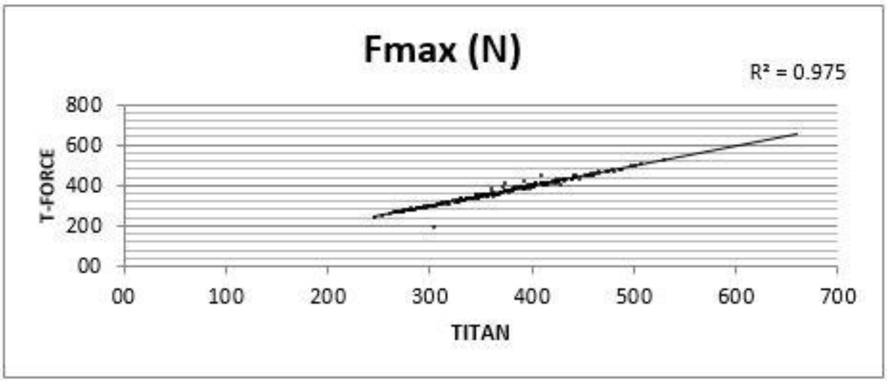

FIGURE 4: Descriptive Statistic. Linear Regression. Maximum Force (Fmax).

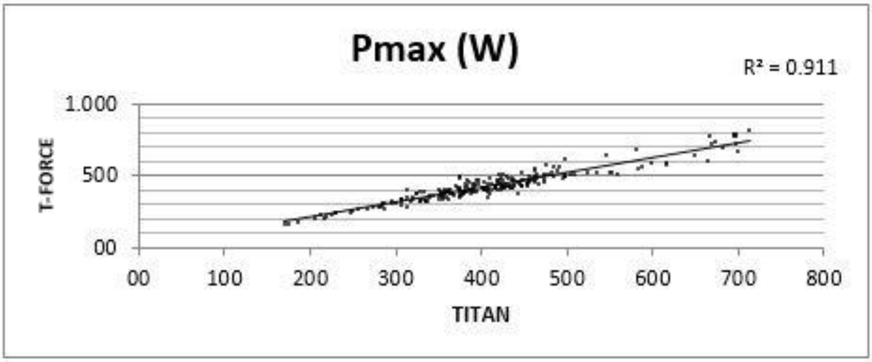

FIGURE 5: Descriptive Statistic. Linear Regression. Maximum Power Peak (Pmax).

In table 1, descriptive data are shown in the two series carried out, one at 50% and the other at 70% of body weight, presenting the following statistic data of TITAN and T-Force: Mean, Standard Deviation and the coefficient of variation.

TABLE 1
Descriptive Statistics (M=Mean, SD=Standard Deviation and CV=Coefficient of Variation) of the data of ten subjects, at 50% and 70% for each measuring instrument.

		Maximum Power Peak		
		M	SD	CV
n=100 (50%)	T-FORCE	255.029	36.918	1487.413
	TITAN	258.632	41.157	1802.911
n=100 (70%)	T-FORCE	300.707	33.380	1165.176
	TITAN	272.403	40.614	1730.821
		Maximum Force		
		M	SD	CV
n=100 (50%)	T-FORCE	500.922	34.039	1587.192
	TITAN	489.655	34.666	1666.184
n=100 (70%)	T-FORCE	636.842	35.253	1756.479
	TITAN	640.712	36.426	1840.624
		Maximum Velocity		
		M	SD	CV
n=100 (50%)	T-FORCE	0.620	0.157	0.007
	TITAN	0.605	0.087	0.008
n=100 (70%)	T-FORCE	0.566	0.129	0.004
	TITAN	0.546	0.127	0.005
		Maximum Acceleration		
		M	SD	CV
n=100 (50%)	T-FORCE	2.873	0.868	0.893
	TITAN	2.833	0.882	0.933
n=100 (70%)	T-FORCE	2.243	0.601	0.538
	TITAN	2.257	0.597	0.552

In table 2, Coefficient of Determination, Pearson's Correlation Coefficient, Intraclass Correlation Coefficient and Coefficient of Variation, corresponding to maximum velocity, maximum acceleration, maximum force and maximum power peak are represented.

TABLE 2
Descriptive Statistics (R2=Coefficient of Determination, PCC=Pearson's Correlation Coefficient, ICC= Intraclass Correlation Coefficient and CV=Coefficient of Variation) for each measuring instrument of the total data.

				CV	
	R^2	PCC	ICC	TFORCE	TITAN
Vmax	0.956	0.978	0.978	19.739	19.612
Amax	0.991	0.995	0.995	38.488	36.471
Fmax	0.975	0.987	0.987	21.473	17.131
Pmax	0.911	0.954	0.954	24.862	26.048

In spite of not finding a normal standard for the parallelism values, since the sensors do not offer identical values, we observe that a high correlation exist amongst subjects, attending the differences between each test on the given weight. The ES was 0.3, α level was set at 0.05, and power (1-β) was 1.0.

DISCUSSION

The data obtained was compared by both instruments used in this investigation and controlled, by way of an autocorrelation, of the subjects in the total number of trials. This strategy in the design was due to the major data variability to the data occurred when sportists were being evaluated (14).

It wasn't possible to obtain a statistic model to allow comparison between our results and those of other trials, having used the same measuring instruments. However, high correlations were notably present on the data obtained by the apparatus going through the trial, this particularly being in contrary to other trials between the various instruments (8, 12, 14, 22). The mean values of Maximum Velocity, Maximum Acceleration, Maximum Force and Maximum Power Peak from the two systems were found to be equivalent. The size effect of the sample was small. It has been postulated that an ICC index of at least 0.9 should be considered for clinical applications (1). Every parameter considered here satisfies such threshold.

Consequently, the statistical analysis carried out would confirm a strong relative validity for each kinetic system, specifically for measuring Maximum Velocity, Maximum Acceleration, Maximum Force, and Maximum Power Peak for the bench press movement.

Practical Applications

The TITAN inertial movement unit represents a portable, wireless, valid, reliable and precise instrument to measure maximum speed, maximum acceleration, maximum strength and maximum power peak during the bench press trials in the concentric phase, being able to use this movement for the evaluation.

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