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ORIGINAL ARTICLE

STANDARD ERROR OF THE CENTER OF MASS (CM) POSITION IN A THREE DIMENSIONAL SPACE OBTAINED THROUGH KINECT™

Erro Padrão da posição do Centro de Massa (CM) no espaço tridimensional obtidas através do Kinect™

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ABSTRACT

Analysis, diagnosis and intervention methods in the biomechanics approach of the human movement have shown to be a field in need of new tools concerning health sciences, sports, quality of life and related areas. Therefore, this very study has the objective of verifying standard error of the Centers of Mass (CM) on human body segments through Microsoft™ Kinect™. Methods: a single subject, height 1.87m, wingspan 1.75m, and body mass 101.10kg, was placed 3.60m far from Kinect's™ lens. For data collecting, the subject was instructed to walk towards the forementioned hardware in a straight line until reaching the marked distance of 1.80 from it, and then return to the starting position, repeating this movement thrice. Data acquisition rate was set at 30Hz, and 14 body segments CM positions were captured on X, Y and Z axes related to the global referential. Data were filtered by FFT, 7Hz cut-off. Standard error was calculated in all of the three situations. Results: the standard error calculated for the 14 body segments CM matched an equivalent of 1.0x10-4m (meaning tenths of millimeters). Those results corroborate other tests already run, such as accuracy, precision and RMS error tests, consolidating Kinect™ potentiality as an analysis, diagnosis and intervention instrument for health sciences, sports, medicine, logistics, marketing, human movement, among other fields.

Keywords: Standard Error; Biomechanics; Center of Mass

RESUMO

Métodos de análise, de diagnóstico e de intervenções no aspecto biomecânico do movimento humano tem demonstrado ser um setor carente de novas ferramentas no que se trata das ciências da saúde, esporte, qualidade de vida, e áreas afins. Sendo assim, o presente estudo tem por objetivo verificar o erro padrão dos Centros de Massa (CMs) dos segmentos corporais com a utilização do Kinect® da Microsoft™. Métodos: Um sujeito com estatura de 1.87m, envergadura de 1.75m e massa corporal de 101.100kg foi posicionado à distância de 3,60m da lente do Kinect®. Para a coleta dos dados, o voluntário foi orientado a caminhar em direção ao referido hardware, em linha reta, de modo que o mesmo chegasse a distância demarcada de 1.80m do mesmo e voltasse à posição de saída, repetindo essa movimentação três vezes. A taxa de aquisição de dados foi de 30Hz e capturadas as posições dos Centros de Massa (CMs) de quatorze segmentos corporais, nos eixos X, Y e Z em relação ao referencial global. Tais dados foram filtrados com FFT e cut-off de 7 Hz, e calculado o erro padrão nas três situações. Resultados: O erro padrão calculado para a posição dos 14 CMs foram da ordem de 1,0.10-4m, ou seja, de décimos de milímetros. Tais resultados corroboram outros testes já realizados, tais como testes de acurácia, precisão e erro RMS, consolidando a potencialidade do Kinect® como instrumento para análise, diagnóstico e intervenção na área das ciências da saúde, esporte, medicina, logística, marketing, movimento humano, dentre outras.

Palavras chave: Erro Padrão; Biomechanics; Centro de Massa.

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INTRODUCTION

Instruments development and validation for the human movement analysis presents great relevance both in academic environment and daily life situations. The hardware Kinect™ by Microsoft™ has demonstrated great potentiality in this way for application into medicine, physical therapy, sports, neurology, orthopedics, among other related areas, attending the anxiety for the human movement analysis[1].

The mentioned hardware presented a great evolution from its first to its current version. For example, improving the sight field 23% and up to 200% when it comes to the ability of identifying a number of individuals simultaneously[2].

Concerning Kinect™ reliability, systematic and random errors, accuracy and precision, several studies approach those aspects[1,3,4,5,6,7,8,9]. Otherwise, even considering those physics quantities calculations, the Root Mean Square (RMS) value still consists in the most adequate method for instruments validation processes, even though it remains associated to the static positioning, once it demands a fix referential value to allows its calculation[10,11].

Determining the CM of a certain body segment must not be mistaken for its Center of Gravity. This last one is defined as a point in a segment upon which the gravity force is applied, also being identified as barycenter. Otherwise, CM is a fix point that represents a body or a bodies cluster whole mass, meaning it is a point that behaves as if all of the mass from that segment were concentrated on it[12].

Calculating RMS error values for the body segments CM through Microsoft™ Kinect™ demonstrated satisfactory results. However, such admeasurement has been performed with an individual on orthostatic position. Otherwise, it suggests[2] the calculation of the standard error values having the assessed subject moving, which is the objective of this study.

METHODS

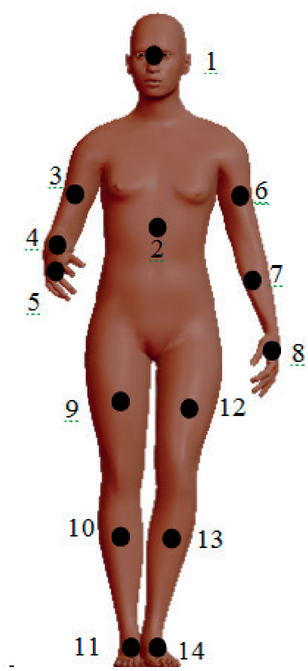
It has been developed specific software for the CM coordinates acquirement from each body segment using C# programming language, through Visual Studio 2013™ and Kinect for Windows™ SDK 2.0 software. The minimal configuration demanded for that software utilization are, Windows 8; 64 bits (x64) dual-core 3.1GHz data processor; 4GB RAM; 3.0 USB door dedicated exclusively to Kinect for Windows or Kinect V2 connection. This last one requires an adapter.

Kinect™ was set on a three feet stand, and its lens optical center has been kept parallel to the floor at 0.75m from it. A single subject, height 1.87m, wingspan 1.75m, body mass 101.10 kg, was placed 3.60m far from Kinect's™ lens. For data collecting, the subject was instructed to walk in a straight line towards Kinect™ until reaching the marked distance of 1.80m from it, then returning to starting position, and repeating this movement thrice. Data acquisition rate was set at 30 Hz and 14 body segments CM positions were captured on X, Y and Z axes related to the global referential. Those data were filtered by FFT, 7 Hz cut-off, accordingly Okazaki et al[13].

As the movement for data collecting was drilled, the subject started to move from the starting position. The demand of the subject's body segments CM was to be analyzed[13] according to Figure 1.

Figure 1 - Centers of Mass (CM) localization

(1) Head – C7-T1 to ear canal.
(2) Trunk – Greater trochanter to glenoumeral joint.
(3) Upper Arm Right (6) Upper Arm Left – Glenoumeral joint to wrist center.
(4) Forearm Right, (7) Forearm Left – Elbow to wrist center.
(5) Hand Right, (8) Hand Left – Wrist center to knuckle II of third finger.
(9) Thigh Right, (12) Thigh Left – Hip to knee center.
(10) Leg Right, (13) Leg Left – Knee to ankle center.
(11) Foot Right, (14) Foot Left – Ankle to ball of foot.



This research has been submitted and was approved by the Committee of Ethics and Research from the Methodist University of Piracicaba (CEP-UNIMEP) under protocol #49/2014 according to the National Health Council rules #466/2012. The subject volunteered himself and signed a Free Consent Form.

Statistic data treatment by Levine equation aimed to verify the Effect Size (ES)[15] due to minimize any possible type II[16] error occurrences. Power Test matched 0.80, and ANOVA two-way adopted as significance $p \leq 0.05$. Origin 9.0 software was utilized to run data for both treatment and statistical analysis.

RESULTS AND DISCUSSION

Effect size was calculated for each body segment (**Table 1**).

Table 1. Effect Size values for each body segment CM on three axes

Segment	X	Y	Z
Head	0.3163	0.2173	0.2205
Trunk	0.3271	0.2285	0.2334
Upper Arm Right	0.3324	0.2319	0.2466
Upper Arm Left	0.0069	0.2293	0.2227
Forearm Right	0.3259	0.2419	0.2758
Forearm Left	0.0649	0.2192	0.2116
Hand Right	0.2968	0.2467	0.2941
Hand Left	0.0894	0.1799	0.1260
Thigh Right	0.3849	0.2256	0.3571
Thigh Left	0.1488	0.2313	0.2716
Leg Right	0.3305	0.2116	0.3390
Leg Left	0.0081	0.2072	0.2469
Foot Right	0.2744	0.2232	0.2695
Foot Left	0.0444	0.1938	0.2273

The obtained Effect Size results (Table 1) are considered small accordingly Cohen criteria. Otherwise, we shall highlight it is inversely proportional to the sample size. In **Table 2** it is possible to find quite satisfactory results for Microsoft™ Kinect™ validation process as a potentially promising tool for three dimensional analysis of the human movement in a broad applicability spectrum and as a consequence, comprising its use in clinics, rehabilitation and sports.

Table 2. Mean, standard deviation and standard error values for CM position during walking movement.

	X(m)			Y(m)			Z(m)		
	Mean	±SD	SE	Mean	±SD	SE	Mean	±SD	SE
Head	1.5323	0.0191	0.0001	1.1904	0.1062	0.0004	0.3828	0.1075	0.0004
Trunk	1.5344	0.0191	0.0001	1.2692	0.0875	0.0004	0.3042	0.0888	0.0004
Upper Arm Right	1.4668	0.0355	0.0001	1.2891	0.0796	0.0003	0.3018	0.0874	0.0004
Upper Arm Left	1.6004	0.0145	0.0001	1.2833	0.0832	0.0003	0.2895	0.0834	0.0003
Forearm Right	1.4365	0.0459	0.0002	1.3836	0.0529	0.0002	0.2319	0.0700	0.0003
Forearm Left	-0.0577	0.0207	0.0001	0.1894	0.0550	0.0002	0.9784	0.0114	0.0000
Hand Right	1.4113	0.0565	0.0002	1.4881	0.0242	0.0001	0.1803	0.0612	0.0003
Hand Left	-0.0748	0.0264	0.0001	0.0845	0.0282	0.0001	0.9929	0.0044	0.0000
Thigh Right	0.0709	0.0251	0.0001	0.0897	0.0233	0.0001	0.9928	0.0039	0.0000
Thigh Left	0.0095	0.0113	0.0000	0.0901	0.0242	0.0001	0.9955	0.0022	0.0000
Leg Right	0.0863	0.0301	0.0001	-0.0715	0.0285	0.0001	0.9928	0.0046	0.0000
Leg Left	-0.0034	0.0082	0.0000	-0.0712	0.0299	0.0001	0.9970	0.0021	0.0000
Foot Right	0.0800	0.0251	0.0001	-0.2473	0.0868	0.0004	0.9611	0.0241	0.0001
Foot Left	0.0067	0.0041	0.0000	-0.2409	0.0876	0.0004	0.9663	0.0214	0.0001

In **Table 2** it is possible to find quite satisfactory results for Microsoft™ Kinect™ validation process as a potentially promising tool for three dimensional analysis of the human movement in a broad applicability spectrum and as a consequence, comprising its use in clinics, rehabilitation and sports.

CONCLUSION

The calculation of the Standard Error for the 14 body segments CM matched an equivalent of 1.0x10-4m (meaning tenths of millimeters). Those results corroborate others tests that have already been run, such as accuracy, precision and RMS error tests[1,2], consolidating Kinect™ potentiality as an instrument for analysis, diagnosis and intervention on health sciences, sports, medicine, logistics, marketing, and human movement fields, among others.

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Obs: Os autores declaram não existir conflitos de interesses.