技 術 報 告

AN ESTIMATE OF MASS MOMENT OF INERTIA (I_0) ABOUT HIP JOINT FOR THE HUMAN ENTIRE LOWER EXTREMITY*

PART 1

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When a dynamic study of the human body links is attempted, the mass moment of inertia is one of the important parameters involved. Clinically measuring the mass moment of inertia may be accomplished with relatively large standard error, while cadaver measurements result in smaller errors. They are thereby considered to be good references for the values measured clinically.

Dempster (1955) reported the calculated values of the mass moment of inertia utilizing the cadaver measurements in Table 2 by equation (1) in Table 1-a. The values of the mass moment of inertia for the entire lower extremity about hip joint (I_0') are listed in Table 2.

The I_0' obtained, however, must satisfy the equation (2) in Table 1-a. As the T_s are not described by Dempster, they are calculated utilizing the cadaver measurements and I_0' s in Table 2 by equation (3) in Table 1-c; thereafter listed in Table 3, termed such as T' . As a matter of fact the expected value of T_s should be around 1.5 seconds, consequently, they are unreasonably large values.

When the values of weight in grams are mistakenly used, meanwhile, to calculate the I_0' s instead of the mass in g·sec²/cm in the equation (1), the I_0' will result in;

$$I_0' = I_0 \times g$$

Thus the calculated T' will be;

$$T' = T \times g^{1/2} \div T \times 31.30$$

The corrected T_s are also listed in Table 3 respectively.

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which obviously provide reasonable values for the period of oscillation. One must therefore come to a conclusion that Dempster used the values of weight in grams for the mass in the equation (1) mistakenly to calculate I'_0 s.

Consequently, the values of I'_0 s described by Dempster may be reasonably corrected by g ;

$$I_0 = I'_0 / g$$

The corrected values, listed in Table 3, are considered to be a good reference for the mass moment of inertia of the human entire lower extremity about the hip joint.

TABLE 1. EQUATIONS & PARAMETERS USED (DEMPSTER)

a. Equations Used¹⁾;

$$I_0 = MghT^2 / 4\pi^2 \quad (\text{g. cm. sec}^2) \quad \dots\dots\dots (1)$$

where T , period of oscillation (sec)

I_0 , mass moment of inertia (g. cm. sec²)

M , mass (g. sec²/cm)

g , acceleration due to gravity (cm/sec²)

h , distance from hip axis to C. G. (cm)

$$T = 2\pi (I_0 / Mgh)^{1/2} \quad (\text{sec}) \quad \dots\dots\dots (2)$$

b. Parameters²⁾;

Average Length of Lower Extremity as Ratio to Whole Body Length for the Medium Somatotype;

Pubis to Floor Body Length

$$89.3 \pm 3.8 \text{ (cm)} / 176.6 \pm 4.9 \text{ (cm)} = 0.506$$

($n = 11$)

($n = 10$)

Distance from Hip Axis to C. G. ; $0.434 \times$ Lower Extremity Length

- c. The h in equations (1) and (2) is calculated to be
 $0.220 \times \text{Body Length}$ from the values provided in b.
 Thus the equation (2) may result in ;

$$T \div 2\pi (I_0 / Mg \times 0.220 \times \text{Body Length})^{1/2} \quad (\text{sec}) \quad \dots\dots (3)$$

TABLE 2. CADAVER MEASUREMENTS (DEMPSTER)³⁾

Cadaver #	Somatotype	Age (yrs)	Supine Height (cm)	Body Weight (g)	Entire Weight (g)	Lower I_0^1 (g. cm. sec ²)	Extremity
14815	medium	67	168.9	51364	L 6255	L 13.3 x 10 ⁶	
15059	medium	52	159.8	58409	9855	13.7	
15062	medium	75	169.6	58409	8390	14.0	
15095	medium	83	155.3	49886	8313	12.3	
15097	medium	73	176.4	72500	11907	24.6	
15168	medium	61	186.6	71364	11111	26.8	
15250	medium	?	180.3	60455	11337	26.7	
15251	medium	?	158.5	55909	8092	15.5	
					R 6176	R 12.6 x 10 ⁶	
					9580	13.4	
					8303	13.6	
					7715	13.2	
					11920	26.0	
					11904	25.5	
					11791	24.5	
					8457	15.0	

TABLE 3. CORRECTED VALUES

Cadaver #	T' (sec)	T (sec)	I ₀ (g. cm. sec ²)
14815	L 47.53	L 1.52	13.6 x 10 ³
15059	39.51	1.26	14.0
15062	42.02	1.34	14.3
15095	41.35	1.32	12.6
15097	45.84	1.46	25.1
15168	48.16	1.54	27.3
15250	48.41	1.55	27.2
15251	46.57	1.49	15.8
	R 46.56	R 1.49	12.9 x 10 ³
	39.63	1.27	13.7
	41.63	1.33	13.9
	44.46	1.42	13.5
	47.11	1.50	26.5
	45.39	1.45	26.0
	45.48	1.45	25.0
	44.81	1.43	15.3

BIBLIOGRAPHY

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(和 文 要 旨)

股関節回転中心に関する人体下肢慣性モーメント (I_0) の推定値について

そ の 1

人体関節機構の動力学的研究にたずさわる者にとって、慣性モーメントは重要なパラメーターの1つである。臨床的に人体各部の慣性モーメントを測定することは不可能ではないが、通常は死体計測値に比べ誤差が大きい。それ故にある意味で、死体計測値は臨床的計測に際しよい指標となる。

1955年 DEMPSTER は8死体16肢の慣性モーメントを測定し報告している。彼が計算に用いた数式ならびに測定値は、それぞれ表1-aと表2に示してある。又彼が計算により求めた股関節に関する下肢慣性モーメント (I_0') も表2右に示した。しかしながらこの値は、臨床的測定値あるいは他の報告にみる値に比べ約1000倍も大きい値である。以下にその検算を行ってみた。

求められた I_0' は、公式(2)も満足させるはずであり、DEMPSTER の測定した自由振動周期 T は記載がないので公式(3)により計算し、 T' として表3に示した。通常人体下肢の自由振動周期は1.5秒前後であるのに比べ、求められた T' は約30倍も大きい。

もしも彼が質量 M のところに誤って下肢重量を代入したとすれば、求められた I_0' は；

$$I_0' = I_0 \times g$$

となり、従って T' は；

$$T' = T \times \sqrt{g} \div 31.30 \times T$$

となるであろう。補正された T は表3に示した通りである。補正值は下肢の自由振動周期として妥当なものである。従って質量 M に重量が代入されていると考えざるを得ないわけで、DEMPSTER の求めた I_0' は重力加速度 g で除することにより妥当な値に補正され

る。補正された I_0 は表3に示した通りで、臨床的生体計測時のよい参考となるものである。

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PART 2

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An attempt was made to estimate the mass moment of inertia (I_0) about hip joint for the human entire lower extremity with knee extended, in respect of subjects with known parameters such as body weight and body length. Utilizing the values measured by Dempster¹⁾, several regression models such as single or multiple linear regression and non-linear regression have been analyzed. The regression analysis by means of analysis of variance (ANOVA)²⁾ is provided in Table 1.

When a single linear regression is utilized, the body length is slightly better parameter than the body weight to estimate the values of mass moment of inertia (I_0') described by Dempster¹⁾; however, a multiple linear regression with two parameters such as body length and body weight provides a significantly better standard error of the estimate for I_0' than a single linear regression model ($P < 0.05$).

Within the range of interpolation as expected, a cubic regression model resulted in the best standard error of the estimate among six models examined though there is no significant difference over a multiple linear regression model (f) where the Dempster's values of body weight are rounded off to a maximum error of ± 500 grams. It may be concluded that there is no advantage to apply the models designated (a), (b), (c) and (e) over the models (d) and

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