INVESTIGATING OF FORCES, TORQUES AND WORK THROUGH BIOMECHANICAL INDIRECT MEASUREMENTS OF BACKWARD SOMERSAULT

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The purpose of the study was to investigate the forces and the torque to the joints in different steps in backward somersault using direct measurement method and simple biomechanical relationships proposed by Shahbazi et al. (1998). The experiment were carried out with 15 experienced children aged 11±2 SD years. Each subject performed three backward somersaults with round off. The experiments were filmed and recorded by a 25 Hz, video camera. Therefore two dimensional kinematics analysis yielded the valuable mechanical parameters which confirmed the results achieved by sophisticated force platform and three dimensional analysis systems.

KEY WORDS: somersault, children, modeling

INTRODUCTION: The model we have chosen is a Tucked Backward Somersault with Round-off and with Run-Up. We had then to take into account three steps to analyze. In each step we had to calculate the speed, the angle of take off, the angle of landing, the force of reaction and the force of muscle involved in take off and in landing through simple biomechanicaL relationships. All these parameters can be achieved just by measuring time and distance of each step. A camera with 25 PPS has also been used in order to determine and verity the angles of legs in different steps.

MATHEMATICAL MODEL:

The main relationships used for this model are proposed by Shahbazi et al. (1998). In each step we have time and distance. Therefore we can have the angle of flight as:

$$\theta = \tan^{-1} \frac{g t_f^2}{2R} \qquad (1)$$

Where; R; is the distance of flight; and tf, is the time of flight which can easily be measured. For the time of flight we have used timers of a precision of 10^{-2} s. Shahbazi et al. (1998), while for the distance foot prints have been used to about 10^{-2} m of precision. Having the angle of flight we can easily achieve the take-off velocity as:

$$V_o = \frac{R}{t_f . Cos\theta} \qquad (2)$$

Knowing Vo and θ, the initial velocity components as Vox and Voy can then be calculated. The steps of calculations are carried out as follows:

a) Run-up

The run-up distance and time are measured with 10^{-2} m and 10^{-2} s respectively by adequate timer, then by simple mechanical relationships we can determine Shahbazi et. al. (1998) the speed at the end of the run-up.

$$a = \frac{2x}{t^2} \qquad (3)$$

$$Vr \cdot u = at \qquad (4)$$

Table 1 Mean Standard Deviation of the Kinematics Variables Used for Run-up

K. P Range	t (sec)	R (m)	a (m/s2)	V (m/s)
Max	2.96	7.3	2.46	5.94
Min	2.34	6.35	1.55	4.57
Mean	2.62	6.76	1.99	5.18
SD	0.2	0.28	0.29	0.4

b) Round-off

As we know Shahbazi et al. (1998) the subject does not round-off with the final speed of run-up but with another speed which can be determined by the equations (1) and (2). The results are indicated in table 2.

Table 2 Mean Standard Deviation of Kinematics Variables Used for Round-off

K .P Range	tf (s)	tT.D (s)	tL.D (s)	θT.O(°)	R (m)	Vo (m/s)	FR (N)	Fm (N)	a (m/s2)
Max	0.2	0.24	0.08	0.68	1.23	9.51	3614	-7236	-209
Min	0.12	0.16	0.04	3.61	0.89	5.39	702	-1458	-62
Mean	0.14	0.18	0.06	6.85	1.06	7.1	2055	-3804	-115
SD	0.02	0.02	0.018	2.74	0.09	1.44	1244	-1726	-50

In order to calculate the ground reaction force of touch down in round-off, we know that at touch down the speed of subject becomes zero. Therefore we have according to the mechanical rule;

$$FR = \frac{d(mv_o)}{dt} \quad (5)$$

Where, dt, is the time of touch down, m is the mass of athlete and V_0 is the velocity at touch down. We are now to determine the muscle force necessary for stopping body at landing from round-off. Neglecting the air resistance, the landing speed is the same as in take off. Therefore we can have:

$$a = \frac{V_o^2}{2Y} \quad (6)$$

Y is the difference between the height of CG (Center of Gravity) at stance state and the height in touch down state with minimum angle. The negative sign indicates the deceleration caused by the legs muscle forces. The legs muscle forces are finally determined by:

$$F \cdot m = -m(a + g) \quad (7)$$

c) Backward somersault

The same steps as were carried out in round-off can exactly be carried out in backward somersault except that in this case we will have to calculate the legs muscle forces for the backward somersault to take place. Therefore, in order to calculate this, we would need the initial velocity of backward somersault. This velocity is again determined by the equation (1) and (2). The results are indication in table (3).

Table 3 Mean Standard Deviation of Kinematics Variables used for backward somersault

K.P Rang	tf(s)	tLD(s)	θTO(°)	θT.D(°)	R(m)	VO(m/s)	FR(N)	FmTO(N)	FmTD(N)	aTO(m/s2)	aTD
Max	0.68	0.32	65.5	147	1.7	5.43	1920	3171	2306	81.9	49.9
Min	0.42	0.08	37.97	108	0.82	3.28	567	718	570	19.21	11.69
Mean	0.56	0.14	54.23	124.7	1.25	3.82	1189	1344	1013	34.34	23.22
SD	0.06	0.06	7.85	12.7	0.24	0.67	338	643	435.5	18.38	10.59

The touch down and take off angles and also the difference between the height of CG at stance and at the minimum knee angle were measured with transparencies and engineering tools for graphs and stick figures Kilani et al. (1998).

WORK, POWER AND TORQUE CALCULATION: The difference in kinetic energies is equal to the work done by muscle. Hay (1993) we can then have respectively:

1) *Work done at landing in round-off:*

$$W = \frac{1}{2} m V_{ro}^{2} \qquad (8)$$

2) *Work done at take off for backward somersault*:

$$W = \frac{1}{2} m V_{Ob.s.}^{2} \qquad (9)$$

3) *Work done at final landing.*

The power is then easily calculated by dividing the work done by the time spent in stopping the center of gravity.

The torque applied to the knee and hip can also be easily calculated by biomechanical relationship:

$$T = F \cdot d \cdot \sin\theta$$

where, F, is either reaction or muscle force and, d, is the distance between the force applied and the joint in question. The results are indicated in table 4.

Table 4 Mean Standard Deviation of Work, Power and Torque Applied to the Joints

K.P Range	W1(j)	W2(j)	W3(j)	P1(w)	P2(w)	P3(w)	TRK(N-m)	TRH(N-m)	TmK(N-m)	TmH(N-m)
Max	1492	557	557	12433	995	995	437	1000	199	396
Min	315	130	130	1815	232	232	25	172	16	88
Mean	803	226	226	5749	375	375	258	535	103	215
SD	373	109	109	3605	205	205	111	224	53	87

DISCUSSION AND CONCLUSION: Our method is based on mathematical and mechanical aspects and very easy to be used, this method needs a camera and a VCR preferably 50Hz or more. The results in accordance with what obtained by Kerwin et al. (1993), Cheethum et al. (1998). This method offers a simple indirect measurement possibility in the absence of expensive 3D and force plate and EMG systems.

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