EFFICIENCY OF OVERARM THROWING

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The term "Mechanical Efficiency" is commonly used in the discussion of Biomechanics. And a lot of studies as for mechanical efficiency have been made on the relationship betreen work performed and corresponding enery cost in such fundamental movements as walking (Margarla 1963, Cavagna and Kaneko 1977), running (Cavagna et al. 1966, Di Prampero 1974) and bicycling (Garry and Whishart 1934, Whipp and Wasserman 1969). However, little was reported concerning mechanical efficiency of overarm throwing movement patterns used in Baseball, Team Handball and Basketball, and to discuss the relationship between the mechanical efficiency and three different types of throwing movement patterns from the point of ball size and weight.

METHOD

Thirty Japanese intercollegiate male athletes were candidated in this study. Table 1 summarized the mean values and standard deviation for the physical characteristics of the subjects. The subjects were randomly tested in following three tests.

Test I Maximal ball velocity test.
The subjects threw a ball in a horizontal plane, using their best effort. Two trials were given for each subject and the fastest one was used for analysis.

TABLE 1. PHYSICAL CHARACTERISTICS OF SUBJECTS

	Height (cm)	Weight (kg)	$\dot{V}O_2max$ ($l \cdot min^{-1}$)	$\dot{V}O_2max$ ($ml \cdot kg^{-1} \cdot min^{-1}$)
Baseball(n=10)				
$\bar{X}$	169.3	63.0	3.28	52.01
SD	3.78	5.25	0.35	4.49
T.Handball(n=10)				
$\bar{X}$	171.5	66.4	3.39	51.22
SD	6.48	3.69	0.45	3.58
Basketball(n=10)				
$\bar{X}$	178.8	71.8	3.52	49.18
SD	9.15	5.38	0.25	4.01

Test II 5-min overarm throwing with a ball test.
The subjects performed 20 overarm throws per min on 5-min exercise at 70% of each maximal ball velocity according to a metronome. After each throwing the subjects were informed of the resultant ball velocity and asked to adjust predetermined ball velocity.

Test III 5-min overarm throwing without a ball test.
The subjects performed the imitated movements as Test II without a ball.

In Test I and Test II, the ball velocity was measured using CDS photocell system. In Test II and Test III, the expired gas was collected by Douglas bag method during last two minutes on 5-min exercise. O_2 and CO_2 concentrations were analyzed by Scholander technique. The ventilatory volume was measured by dry gas meter. Kilocaloric equivalents were calculated by assuming an equivalent of 5.05kcal/lO_2 (based on an RQ of 1.00). Kinetic energy of the thrown ball was calculated from the following formula: $\frac{1}{2}\cdot m\cdot v^2$ (m: mass of ball v: ball velocity). Net energy expenditure was calculated from $E_L - E_0$ (E_L ; caloric output, throwing with a ball, and E_0 : caloric output, throwing without a ball). Then the mechanical efficiency of the throwing movement was determined by the following formula:

$$\text{Mechanical Efficiency} = \frac{\frac{1}{2}\cdot m\cdot v^2}{E_L - E_0}$$

Forthere, to determine the work intensity in Test II and Test III, maximal oxgen uptake was measured using a progressive work load procedure on Bodyguard bicycle for each subject.

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RESULTS AND DISCUSSION

Fig. 1 shows the differince of maximal ball velocity in each type of throwing movement pattern. The mean values for miximal ball velocity in baseball throwing are 29. 1±3.07 (mean+SD)m/sec. Team handball 21.2±1.31m/sec. basketball 17.6±2.42m/sec. respectively. As for the maximal ball velocity, the value of baseball throwing are the highest of three types of throwing movement. There were the significance of differences in the mean values for maximal ball velocity in the three different types of throwing movement patterns, It was clearly noticed that ball velocity deceased as ball wieght increased, This tendency is similar to previous reports of Toyoshima (1973) and Kunz (1974).

Table 2 presents the mean values and the standard deviation for % of maximal ball velocity in Test II, work intencity in Test II and work intensity in Test III. The mean values for % of maximal ball velocity were 68.5% in baseball throwing. Handball 70.0%, basketball 68.%., respectively. As for work intensity, the values of baseball throwing were the highest in both Test l abd Test ll.

The mean value and the standard deviation for energy expenditure and work in each throwing movement pattern are shown in Fig.2. The mean values for energy expenditure in baseball throwing were 165.1±75.22(mean+SD)cal. Handball throwing

107.8±24.81 and basketball throwing 187.1±56.78cal. respectively. As for work the mean values in baseball throwing 7.7±1.44 (mean+SD)cal. handball throwing 11.6±1.52cal and basketball throwing 10.5±2.09cal. respectively.

TABLE 2. PERCENT OF MAXIMALL BALL VELOCITY IN TEST II, AND WORK INTENSITY IN TEST II AND III.

	%maximal ball velocity in Test II (%)	Work intensity in Test II (% $\dot{V}O_2max$)	Work intensity in Test III (% $\dot{V}O_2max$)
Baseball(n=10)			
$\bar{X}$	68.5	58.4	38.7
SD	1.92	11.33	10.66
T.Handball(n=10)			
$\bar{X}$	70.0	48.0	37.4
SD	1.73	10.29	10.42
Basketball (n=10)			
$\bar{X}$	68.1	47.8	27.5
SD	2.47	9.48	7.37

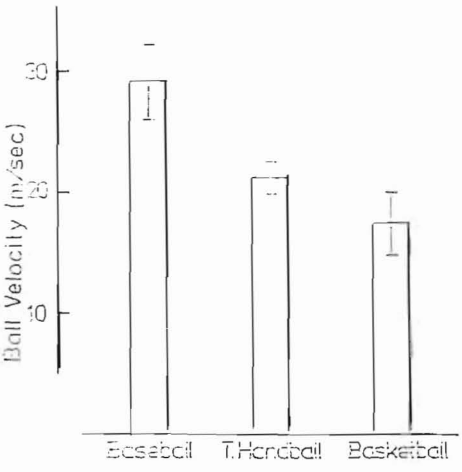

Fig.1 Maximal ball velocity of each throwing movement pattern in Baseball, Team Handball and Basketball.

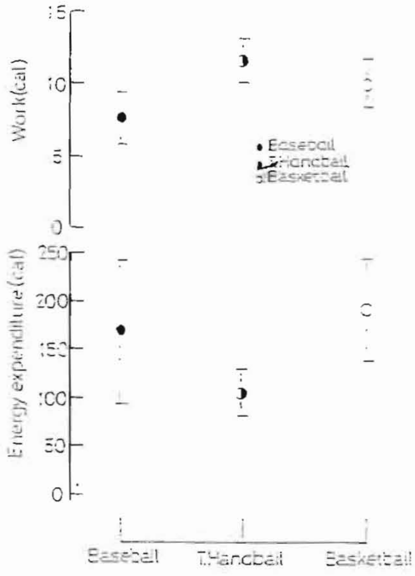

Fig.2 Energy expenditure and Work in each throwing movement pattern.

Table 3 presents the mean values, the standard deviation and ranges for the mechanical efficiency in each throwing movement pattern. In this study the mean values for the mechanical efficiency were 5.7±2.25(mean±SD)%, Handball throwing 10.2±2.23%, basketball throwing 6.3±1.87%, respectively. These values for the mechanical efficiency ranged 3.3% to 14.0%. These values were lower than those of cycling (Whipp and Wasserman 29.8% 1969, Garry and Wishart 24.2-30.6% 1934) and walking (Donovan and Brooks 31.8% 1977). With respect to the mechanical efficiency of handball throwing, the value in this study were higher than those of previous report (Yamamoto and Adrian 3.9% 1984). It is considered that this was caused from the difference of the calculation of mechanical efficiency. According to the report of Whipp and Wasserman (1969), the values of Work efficiency are about 10% higher than the other calculation such as Net efficiency or Gross efficiency. Therefore, this explains why the mechanical efficiency in this study were higher than those of previous studies.

TABLE 3. THE MECHANICAL EFFICIENCY OF EACH THROWING MOVEMENT PATTERN

	Mechanical Efficiency (%)		
	Mean	SD	Range
Baseball (n=10)	5.7	2.25	3.5 – 10.6
T.Handball (n=10)	10.2	2.23	7.0 – 14.0
Basketball (n=10)	6.3	1.87	3.3 – 10.5

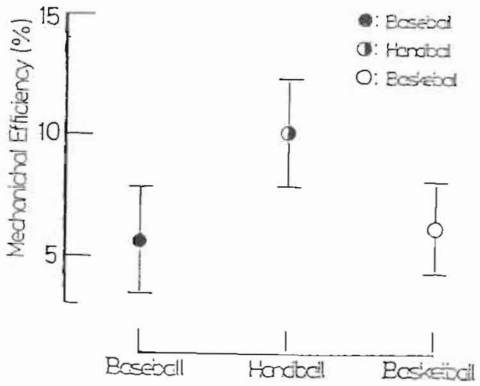

Figure 3. The relationship between mechanical efficiency of three types of overarm throwing

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