Kinematic - Dynamic Analysis of the Support Phase in Different Throws of Handball

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INTRODUCTION

Handball is a sport requiring mobility and a variety of movements during the event. In particular, this can be observed in the different ways of throwing the ball. It has also been proved that the velocity of releasing the ball is different in the different types of throwing (Mikkelsen F. - Olessen 1976, Kastner et al., 1978, Kotzamanidis et al., 1985).

Handball throwing has a complex construction. So one of the significant points of technical perfection is the quality of the impulse transmission from the lower to the upper segments of the body (Muller 1982, Ignateva 1983). Plagenhoef (1971) put forward that this transmission is the coordination of acceleration - deceleration of body segments in sequence beginning from the supporting foot, producing the maximum absolute velocity of the throwing hand.

As it appears this sequence depends on the supporting phase which as it is well known can be divided in the deceleration and the acceleration phases.

When the decelerate phase is contrary to the intended movement then elastic energy is produced and stored in the muscles because of the eccentric contraction. It has been also proved that the first phase must have short duration for a better utilization of this plastic energy. (Cavagna et al., 1968, Hochmuth 1981).

The aim of this investigation was to analyze the forces acting by the low extremeties during the supporting phase of the last stride and to find the relationship between these forces and the velocity of the ball during the delivery.

METHOD AND PROCEDURE

The subjects of this study were 15 handball players, members of the national teams of Yugoslavia, Bulgaria, Rumania and Turkey, aged between 18-23 years.

Throws were analysed kinematically with a highspeed camera, running 100 frames/sec, 16 mm., Locam 51002. The dynamic properties of that movement, were measured with a «kistler» force platform (surface 0,40 × 0,60 m, fig. 1).

Four kinds of throws were described:

1. S.T. : Throws without run-up static (fig. 1).
2. T.W.J.: Throws with run-up (3 strides), without jump (fig. 2).
3. T.V.J.: Throws with run-up (3 strides) and vertical jump (fig. 3).
4. T.H.J.: Throws with run-up (3 strides and horizontal jump (fig. 4).

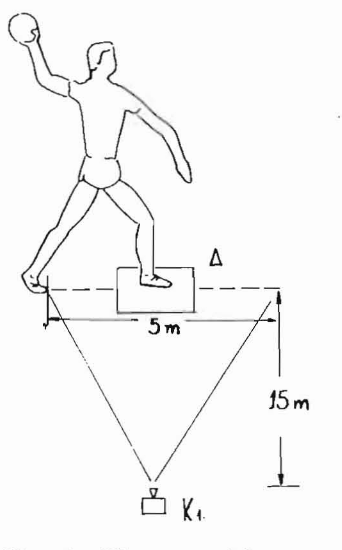

Fig. 1. Throws without run-up (S.T.)

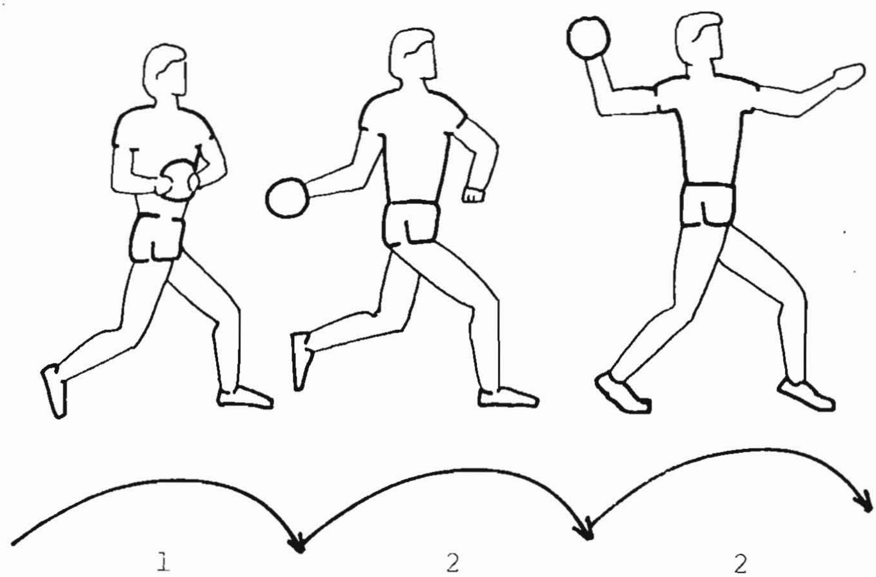

Fig. 2. Throws with run-up without jump. (T.W.J.)

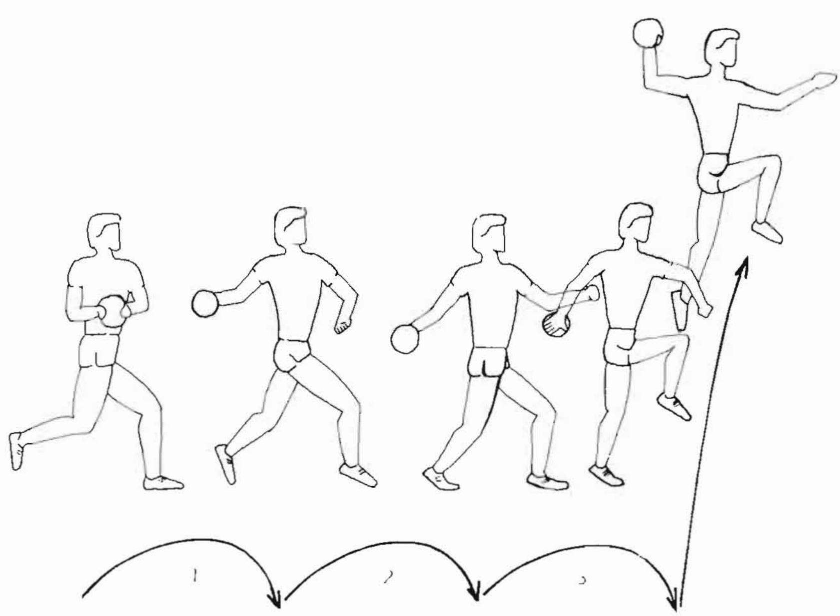

Fig. 3. Throws with vertical jump. (T.V.J.)

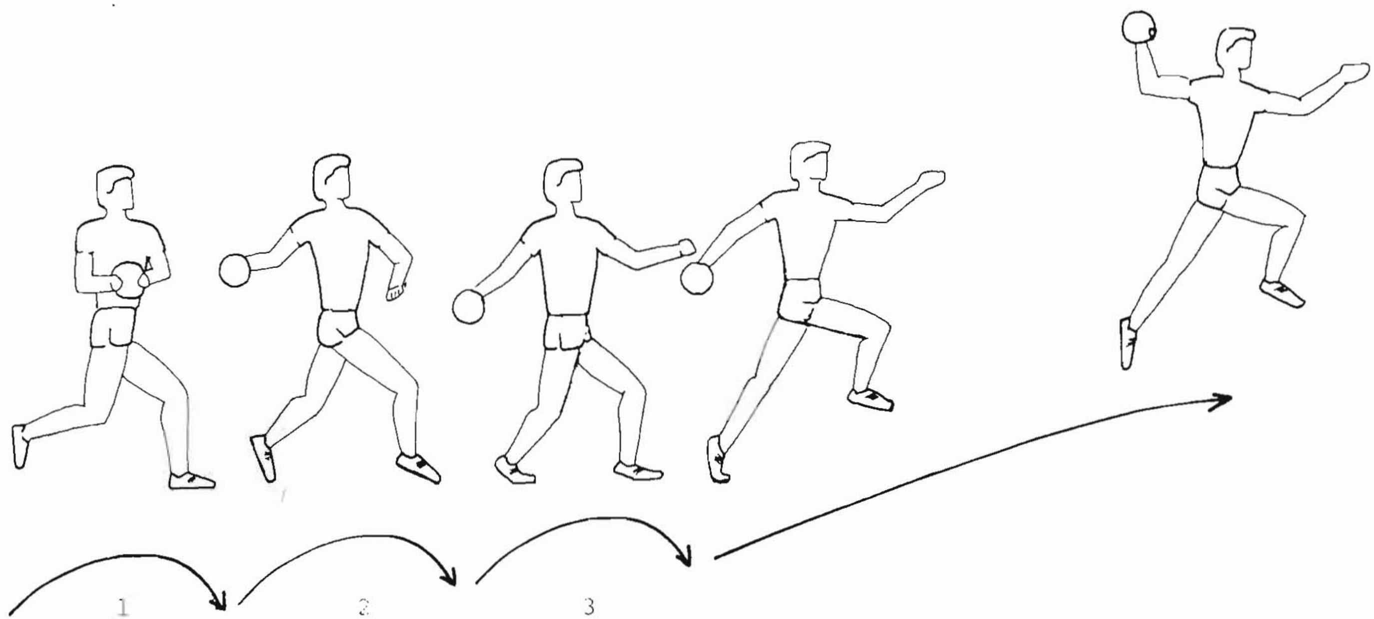

Fig. 4. Throws with horizontal jump. (T.H.J.)

RESULTS AND DISCUSSION

General observations

The mean values of Table 1, show that there is a significant difference in the velocity of the ball (Va) between various throws. The higher value in va is appeared in the throw T.H.J. ($\overline{X}_4 = 25$ m.s^{-1}), follows the T.W.J. ($\overline{X}_2 = 24.75$ m.s^{-1}), and S.T. ($\overline{X}_1 = 24.20$ m.s^{-1}). The lower value was achieved by throw T.V.J. ($\overline{X}_3 = 23.44$ m.s^{-1}).

It is interesting that for all types of throwing the va had a high level of homogeneity ($V_0 < 10\%$) compared with the other analysed parameters ($V_0 > 30\%$).

These data show that throws with the same value of va are obtained with a different technique of support since every player has his own personal style.

Comparative analysis of the throwing without Jumps (table 1)

The means of table 1 show that significant higher values were found for all four time variables, in the static throws (S.T.) as fot tol ($\bar{x}_1 = 0{,}72$s, $\bar{x}_2 = 0{,}57$s), t_1($\bar{x}_1 = 0{,}34$s, $\bar{x}_2 = 0{,}25$s), t_2($\bar{x}_1 = 0{,}37$s, $\bar{x}_2 = 0{,}29$s), tF_z($\bar{x}_1 = 0{,}35$s, $\bar{x}_2 = 0{,}13$s).

Significant difference there is also in the variable F_z, where the value is higher for the T.W.J. ($\bar{x}_2 = 1601$ Nt and $\bar{x}_1 = 1301$ Nt).

An interesting point was observed here. The rest variables of the deceleretion phase have significant higher values in the throw T.W.J. as V_1($\bar{x}_2 = 0{,}97$ m.s^{-1}, $\bar{x}_1 = 0{,}41$ m.s^{-1}) and Fx_1($\bar{x}_2 = 305.37$ Nt, $\bar{x}_1 = 63.47$ Nt). On the contrary, the variables of the acceleration phase have higher values in the throw S.T. as V_2($\bar{x}_1 = 1{,}45$ m.s^{-1}, $\bar{x}_2 = 0{,}36$ m.s^{-1}) and Fx_2($\bar{x}_1 = 86.06$ Nt, $\bar{x}_2 = 75.88$ Nt).

A qualitative difference, is that the players accelerate to the S.T. ($V_2 > V_1$, $V_2 = 1{,}45$ m.s.$^{-1}$, $V_1 = 0{,}41$ m.s^{-1}). In contrast in T.W.J. the players decelerate ($V_1 > V_2$, $V_1 = 0{,}97$ m.s^{-1}, $V_2 = 0{,}36$ m.s^{-1}).

From the above analysis it appears that the players in the T.W.J. decelerating during the supporting phase lose the advantage of the run-up. This can also be supported by the fact that there is no significant difference in Va between the two kinds of throwing ($x_1 = 24.20$ m.s^{-1}, $x_2 = 24.75$ m.s^{-1} $p>0.5$).

This conlusion applies in the above mentioned case only. As stated earlier other studies (Kotzamanidis et al., 1985) on Greek national players, the value of Va in the throw with run-up is significantly higher than Va of throw without run-up. This difference probably means that the players use different technique during the run-up and the supporting phase. This can be supported also by the fact that the level of the two samples is different because the value of Va in Greek players is significantly lower.

Comparative analysis of the throwing with jump (table 1)

The first conclusion drawn for both throwings is that the players tend to decelerate ($V_1 > V_2$).

This could be explained by the necessity of the take off which is required in both throwings.

By examining the mean values of the other variables we can identify two main differences.

Firstly at the T.V.J. the variables of horizontal decelerations have significantly higher values: as the $t_1(\bar{x}_3 = 0{,}22s, \bar{x}_4 = 0{,}18s)$, $V_1(\bar{x}_3 = 1{,}43\ m.s^{-1}, \bar{x}_4 = 0{,}76\ m.s^{-1})$, $Fx_1(x_3 = 445.7\ Nt, x_4 = 309.07\ Nt)$ and they also have a much higher value of coeff. K ($x_3 = 56.45$, $x_4 = 7.65$). Secondly contrary to the first case in the T.H.J. the variables of horizontal acceleration have higher values since $t_2(x_4 = 0{,}06s, x_3 = 0{,}03s)$ to the $V_2(x_4 = 0{,}08\ m.s.^{-1}, x_3 = 0{,}03\ m.s^{-1})$ and to the $Fx_2(x_4 = 93.46\ Nt, x_3 = 48.58\ Nt)$. In T.V.J. throw this could be explained by the necessity of the vertical take off. On the contrary the increase of horizontal acceleration is considered to be essential for the horizontal take off in the T.H.J. throw.

These two differences of the supporting phase in the two types of throwing can explain the significant difference in the value of $V_a(x_4 = 25\ m.s^{-1}, x_3 = 23.44\ m.s^{-1})$.

We can also add that there are no significant differences between the other variables.

Correlation analysis of the throwing without jumps (table 2)

The correlations between the Va and tol at the S.T. and at in T.W.J. were $r_1 = .440$ and $r_2 = .257$ respectively. This means that the higher values of Va were obtained by reducing the tol at the S.T., while at the T.W.J. this variable does not influence significantly the Va.

However, the correlation between the t_1 and Va is very low ($r_1 = .112$, $r_2 = .272$ respectively) which indicates that the time of deceleration phase does not influence the performance in either case. In contrast the negative correlations obtained with the t_2 for bo'h throws and especially for the S.T. show that the players achieve higher values of Va by reducing the time of horizontal acceleration ($r_1 = -.639$ and $r_2 = -.313$).

TABLE 1

Mean scores of the selected variables of the supporting phase and velocity of the ball

Throwing types / variables	Symbol and measured unit	Throwing without jump		Throwing with jump	
		S.T $\bar{x}\pm s_1$	T.W.J. $\bar{x}_2\pm s_2$	T.V.J. $\bar{x}_3\pm s_3$	T.H.J. $\bar{x}_4\pm s_4$
1. Total time of supporting phase	tol (sec)	0,71±0,23*	0,54±0,17	0,25*±0,102	0,24±0,02
2. Variables of horizontal deceleration:					
— time	t_1(sec)	0,34*±0,11	0,25±0,08	0,22*±0,02	0,18±0,03
— velocity	$V_1(m\cdot s^{-1})$	0,41±0,10	0,97*±0,26	1,43*±0,37	0,76±0,29
— force (average)	Fx_1(N)	63,47±54,59	305,37±99,01	445,70±91,66	309,07±33,77
3. Variables of horizontal acceleration					
— time	t_2(sec)	0,37*±0,16	0,29±0,14	0,03±0,01	0,06*±0,02
— velocity	$V_2(m.s^{-1})$	1,45*±1,01	0,36±0,34	0,03±0,01	0,08*±0,04
— force (average)	Fx_2(N)	86,06±35,39	75,88±41,69	48,58±27,30	93,46±31,95
4. Velocity of the releasing the ball	$Va(m.s^{-1})$	24,20±1,64	24,75±1,80	23,44±2,05	25*±1,99
5. Maximum vertical force	Fz(N)	1.301±1,67	1.601*±323	2.999±464	2.825±317
6. Time of appearance of maximum vertical force	tFz(sec)	0,35*±0,20	0,13±0,09	0,13±0,01	0,12±0,02
7. Relationship between momentum of deceleration and momentum of acceleration	coef. K	0,92	2,48	56,45	7,65

n = 15

* There is significant difference, $p\leqq.05$

$n = 15,\ p \leqq 0{,}05,\ r \geqq .480$

A considerable point for both throwings is that the players in order to achieve higher values of Va tend to increase the other variables of the horizontal deceleration phase. This is shown by the obtained correlation of the Va with $V_1(r_1 = .427, r_2 = .390)$ and the $Fx_1(r_1 = .400, r_2 = .483)$. In contrast the low correlation obtained between Va and $V_2(r = .104, r_2 = -.192)$ and $Fx_2(r_1 = .201, r_2 = .138)$ indicate that the players do not use the acceleration phase effectively. This can also be seen in Fig. 5, for the S.T. throw, where the same value of Va was obtained without complete use of the acceleration phase. Furthermore for the T.W.J. throw (fig. 6) higher value of Va can be obtained without any acceleration, during the supporting phase.

The above analysis seems to emphasize that the deceleration contact period has a significant role for achievement of higher values of Va. This could be explained by the fact that the players decelerating during the supporting phase, accelerate other segments of the body which directly affects the velocity of the ball.

The optimal use of the deceleration phase by the players is seemed also by the low correlations obtained between $V_1 - V_2$, $t_1 - t_2$ and $Fx_1 - Fx_2$ ($r < .200$ for all cases). This shows that the acceleration phase is not negatively affected by the magnitude of the deceleration phase. Thus, a question arises that probably the time has come, that some of the current beliefs about the effects of the deceleration phase on the throw, should be revised, at least as far as handball is concerned.

Another interesting point of the «supporting» technique in the S.T. throw is the correlation of Va with the $Fz(r_1 = -.305)$ and the $tFz(r_1 = -.425)$. The correlations obtained here indicate that the lower values of the vertical maximum force and the decrease of the time of its appearance cause the higher values of velocity of the ball.

Analysis of correlation in the throwings with a jump (table 2, Figure 7, 8)

The negative correlations obtained in the T.H.J. between the Va and the tol ($t_4 = -.384$), $t_1(r_4 = -.350)$ indicate that the increase of the Va is due to the reduced total time of the supporting phase and the time of the deceleration phase. On the contrary, the significant correlation obtained between Va and t_2 shows that the increase of time of acceleration phase, causes higher value of Va ($r = .550$).

It has also been observed that these time variables (tol, t_1, t_2) do not influence the Va in the T.V.J. because there are not no significant correlations ($r < 300$ for all cases).

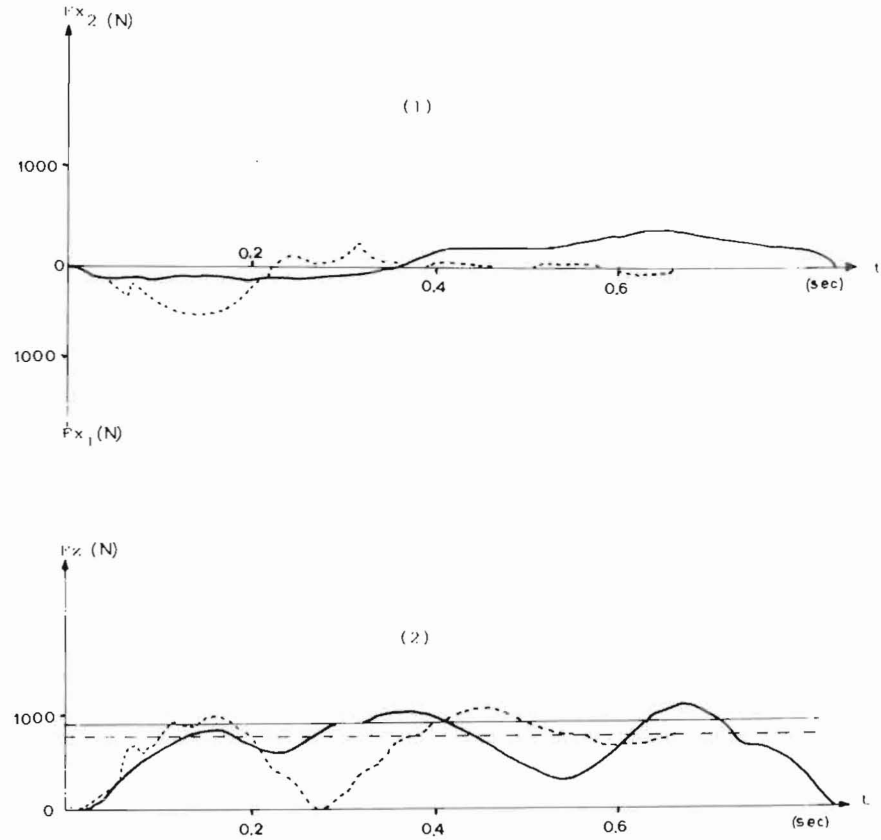

Fig. 5 Ground reaction forces in static throws (S.T.) of two different players:

——— a: V = 24.2 $m.s.^{-1}$

--------- b: V = 24.3 $m.s^{-1}$

(1) Horizontal reaction force

(2) Vertical reaction force

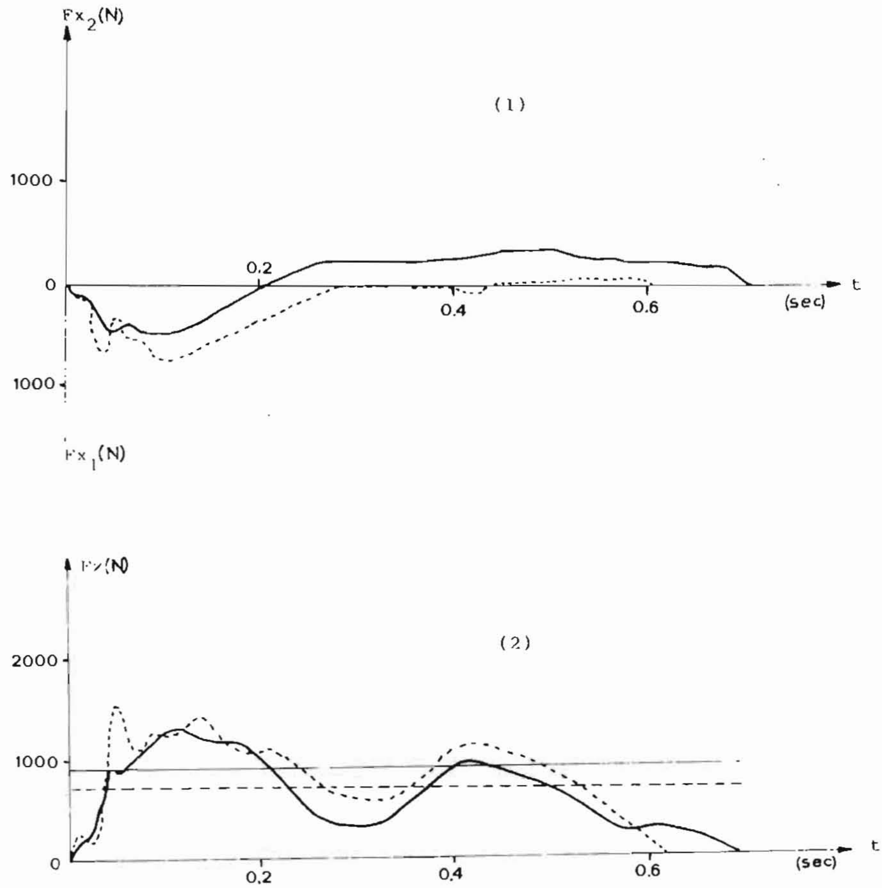

Fig. 6 Ground reaction forces in throws with run-up without jump (T.W.J.) of two different players:

——— a: $V = 25.7\ m.s^{-1}$

--------- b: $V = 27.4\ m.s^{-1}$

(1) Horizontal reaction force

(2) Vertical reaction force

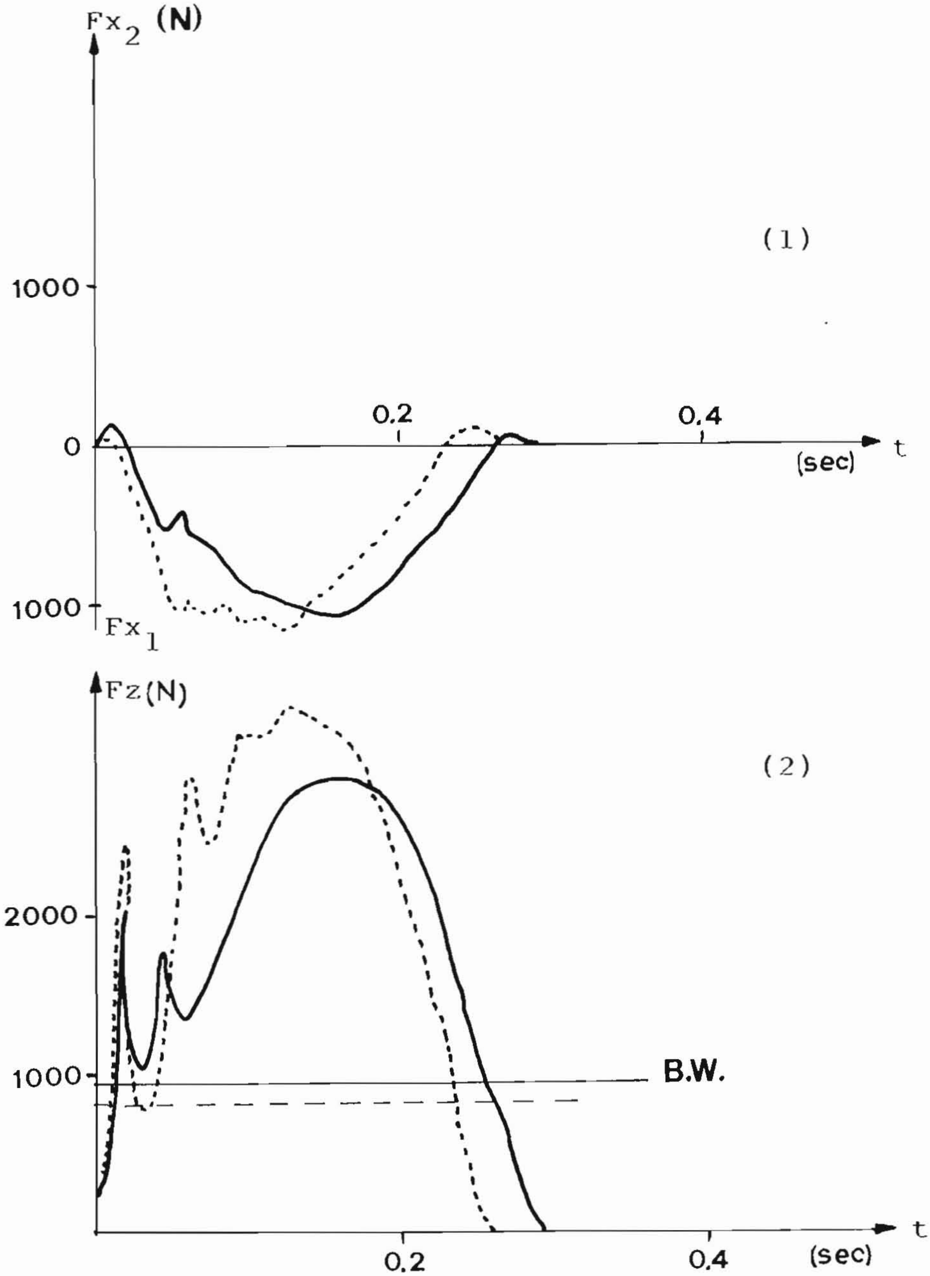

Fig. 7 Ground reaction forces in throws with run-up and vertical jump (T.V.J.) of two different players:

——— a: $V = 26.2\ m.s^{-1}$

--------- b: $V = 19.5\ m.s^{-1}$

(1) Horizontal reaction force

(2) Vertical reaction force

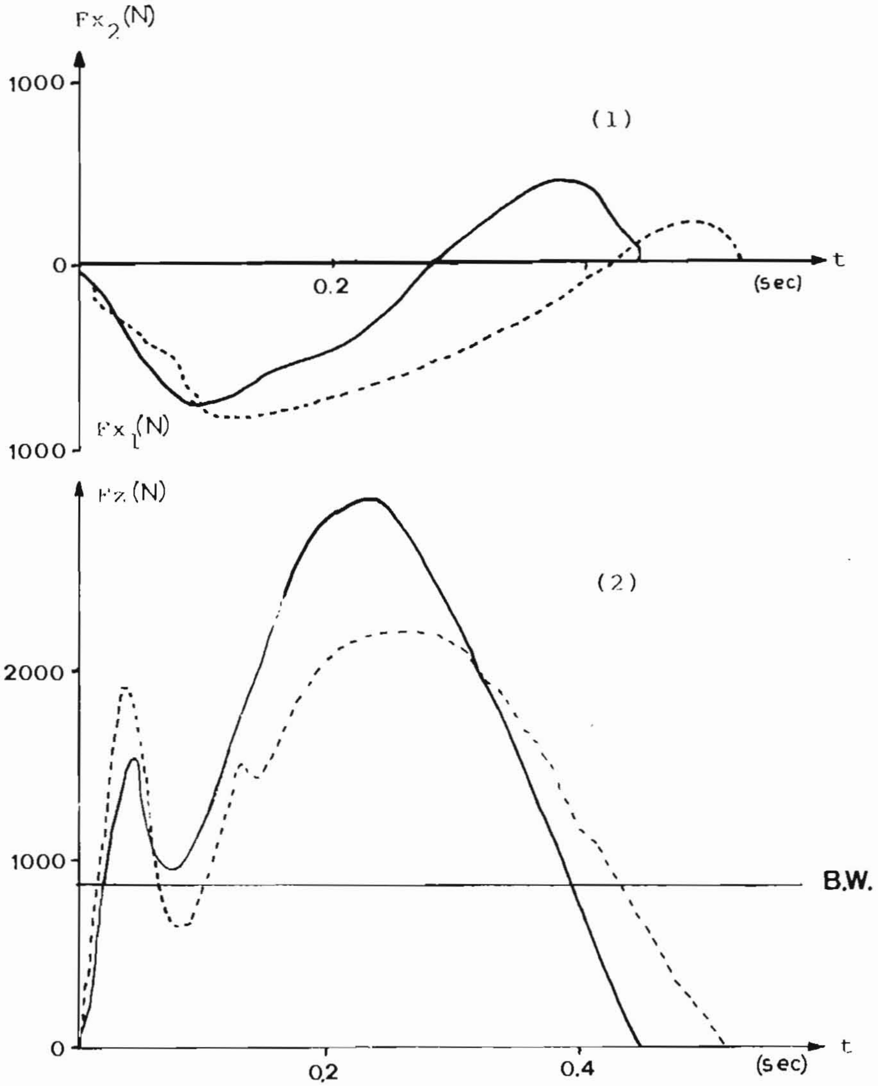

Fig. 8 Ground reaction forces in throws with run-up and vertical jump (T.V.J.) of two different players:

——— a: V = 26.1 $m.s^{-1}$

-------- b: V = 21.03 $m.s^{-1}$

(1) Horizontal reaction force

(2) Vertical reaction force

TABLE 2
The correlations between the variables of the supporting phase and the velocity of ball in different throwing types

throwing types / variables	S.T. r_1	T.W.J. r_2	T.V.J. r_3	T.H.J. r_4
tol	−.440	.257	.032	−.384
t_1	.112	.272	−.009	−.350
t_2	−.639	−.313	.280	.550
V_1	.427	.390	.370	.009
V_2	−.104	−.192	.496	.538
Fx_1	.400	.483	.180	.126
Fx_2	.201	.138	.423	.581
K	.312	.310	−.202	−.205
Fz	−.305	.219	.241	.293
tFz	−.425	−.064	−.464	−.488

$n = 15$, $p \leqq 0{,}05$, $r \geqq .480$

The relationships among the other variables indicate a common tendency of both throwings of the Va to be related with the variables of the horizontal acceleration phase especialy with the T.H.J., as with the $V_2(r_3 = .496,\ r_4 = .538)$ and with the $Fx_2(r_3 = .423,\ r_4 = .581)$.

The obtained results seem to emphasize the importance of the acceleration phase of contact period for achieving higher values of Va. This conclusion is considered normal for the T.H.J., because of the transmission of the horizontal acceleration from the body to the throwing hand. For the T.V.J., this can be explained by the fact that the take-off is not completely vertical but has a small forward-upward direction. So this direction of take-off creates presumptions for a horizontal acceleration, which finally influences the velocity of the ball.

The low correlations obtained between Fz and Va($r_3 = .241$ and $r_4 = .293$) indicate that the maximum value of vertical force does not influence the velocity of the ball. On the contrary the negative significant correlations between Va and tFz in both throws ($r_3 = -.464$, $r_4 = -.488$), indicate that the less the time of appearing the maximum value of tFz, the higher the ball velocity is.

Another interesting point for the technical perfection especially at the T.H.J., is the significant negative correlations obtained between V_1 and $V_2(r_4 = -.883)$ and Fx_1 with the $Fx_2(r_4 = -.581)$ and t_1 with $t_2(r = -.648)$ show that an indirect way for the achievements of higher values of Va, should be the reducing the values of the variables of the horizontal deceleration phase.

CONCLUSION

The analysis of the supporting phase in the four kinds of handball throws, suggests the following:

1. In every throw there are specificities in the utilization of the supporting phase variable.
2. The same value of the velocity of the ball can be obtained with different supporting technique.
3. In the static throws the players tend to accelerate while in the rest throws decelerate.
4. For the throws without jump the phase of the horizontal deceleration (first contact period) seems to have more importance.
5. For the throws with jump and especially for the throw with horizontal take-off is more important the phase of acceleration (second contact period).

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