THE INFLUENCE OF DIFFERENT IMPLEMENTS ON KINEMATICS AND KINETICS COMPARED TO MENS JAVELIN THROW

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The aim of the study was to investigate the influence of different throwing devices on the kinematics and kinetics of the throwing arm. Therefore, six experienced athletes threw six different implements (five balls, one javelin) with different masses. Retroreflective marker data were captured using a 12-camera infrared system. The results show significant differences between the implements, where lighter implements achieve higher release speeds. Furthermore, differences in the shoulder external rotation angle, the angular velocities of shoulder internal rotation and elbow extension, as well as the moments at the shoulder and elbow could be shown. It can be concluded that balls of different masses have similar kinematics and kinetics and can therefore be used to train speed and strength aspects of the javelin throw while using lower run-up speeds.

KEYWORDS: inverse kinetics, upper extremities, modelling, high performance sport.

INTRODUCTION: In order to generate high throwing distances, the highest possible release speed is required (Bartonietz, 2000). The training process is therefore designed to systematically increase the release speed, to prepare the functional system involved for the prospective performance requirements and to achieve technical improvement. In order to achieve these goals, (semi-)specific throws with equipment of different masses and shapes have become established in training practice alongside a variety of other training content. While many studies in baseball have shown that training programs with both, light and heavy throwing implements result in an increase in release speed (Melugin et al., 2021), the use of different implements in javelin throwing is based primarily on experience. In addition to the lack of experimental studies on the effect of different throwing implements on the release speed and the effect of different implements on the kinematics and kinetics is not well examined in javelin throwing. However, in the past, assumptions were made about how different implements affect kinematics and kinetics, which were primarily based on the experience of trainers and expert assessments (Lehmann, 2016). While no assumptions have yet been formulated regarding the effect of form on kinematics and kinetics of the throwing arm, the effects of heavy and light throwing implements can be summarized as follows. The use of heavy throwing implements is intended to support the “bow tension” (Tidow, 2008) by delaying the onset of the action of the throwing arm. Due to the delayed application of the main acceleration, greater forces are required for the acceleration of the implement, heavy implements should therefore contribute to special strength development and, by shortening the acceleration phase, also to special power training (Lehmann, 2016). In contrast, the use of lightweight throwing implements is said to improve specific speed skills as well as the associated control and regulation mechanisms. By reducing the mass, higher partial body and throwing speeds are achieved, which correspond to the speeds to be expected in competition (Lehmann, 2016).

The aim of this study was to investigate kinematic and kinetic differences of the throwing arm (A) between the javelin and throwing balls and (B) between balls of different masses.

METHODS: Six international experienced, male, right-handed javelin throwers (1.91±0.05 m; 97.08±10.66 kg) participated in the study. At the timepoint of the investigation, all athletes were free from injury. Each participant provided written informed consent prior to the data collection. Each participant had unlimited time to warm-up before the investigation. Afterwards each subject was outfitted with 16 retroreflective markers. Also, the javelin was equipped with 5 reflective markers, while the balls had none. Afterwards each participant performed throws with six different implements in a randomized order. Five of these implements were throwing balls (Podium Balls, Birmingham, United Kingdom) with the following weights: 1200 g, 1000 g, 800 g, 600 g and 400 g. In addition, all athletes threw a javelin (GETRA Kinetic 70 m, 800 g, Getrasport, Regensburg, Germany), which was slightly modified for indoor use. While the balls were thrown from a three-step approach (push off from the left leg to the impulse stride – touchdown of the rear leg – touchdown of the bracing leg), the javelin was thrown from the longest approach the athletes were capable of at the timepoint of the investigation. Each participant performed at least three trails per implement.

Three-dimensional retroreflective marker positions were recorded using 12 infrared cameras (Oqus 7+, Qualisys AB, Gothenburg, Sweden) sampling at 250 Hz(Oqus 210c, Qualisys AB, Gothenburg, Sweden) operating at 125 Hz for event detection. An additional camera system, consisting of two orthogonal cameras (rear and throwing side view) operating at 100 Hz was used for the estimation of release speed and angle of release.

To calculate the kinematics and kinetics, a five-segment model (right hand, forearm, upper arm, thorax, abdomen) was used. While the javelin was modeled based on the attached markers, the balls were attached to the hand as a simple sphere. For the inverse-dynamics calculations the body segment inertial parameters provided by de Leva (1996) were used.

For the statistical analysis, the release speed (v_0), the speed of the wrist at the beginning of the delivery (v_E), the duration from the touchdown of the rear leg to the bracing leg i.e. the length of the delivery phase (T_1-T_2), the time between the touchdown of the bracing leg and the release i.e. the length of the main acceleration phase (T_2-T_3), as well as the onset (time before release) of the shoulder internal rotation (T_{IR}) and elbow extension (T_{EXT}) were calculated. Furthermore, from the calculated kinematical and kinetical time series of the shoulder and elbow joint, the following maximal values were extracted: shoulder external rotation angel, shoulder horizontal extension angle, elbow flexion angle, shoulder internal rotation velocity, shoulder horizontal flexion velocity, elbow extension velocity, shoulder internal rotation torque, shoulder horizontal flexion torque, elbow varus torque. In order to statistically compare the data of the different implements, non-parametric tests were used due to the small sample size. The Friedmann test was used to test for unspecific differences between the implements. In case of differences of the omnibus-test, Conover's test was used for pairwise comparisons.

RESULTS: The results of the more general parameters are given in table 1, for the joint angles, angular velocities and joint moments see figure 1.

Table 1: Overview for the release speed (v_0), velocity at the beginning of the delivery (v_E), length of the delivery phase (T_1-T_2), length of the main acceleration phase (T_2-T_3), onset of the shoulder internal rotation (T_{IR}) and elbow extension (T_{EXT}), for the different implements. Values are given as mean (standard deviation), additionally the results of the Friedmann test (X^2) and the corresponding level of significance (p) are shown. Subscript indices show significant differences for post-hoc comparisons (see bottom of the table).

	400g	600g	800g	1000g	1200g	Javelin	X^2	p
v_0 [m/s]	27.0(1.0)^{d,e,f}	25.5(0.8)^{e}	24.5(1.1)	23.1(0.4)^{a}	21.8(0.5)^{a,b}	23.3(0.7)^{a}	27.14	< 0.001
v_E [m/s]	3.45(0.3)	3.47(0.3)	3.49(0.3)	3.48(0.3)	3.45(0.3)^{f}	4.5(0.5)^{e}	13.24	0.021
T_1-T_2 [ms]	405(36)	403(37)	406(20)	410(33)	419(30)	397(44)	7.28	0.201
T_2-T_3 [ms]	136(9)	136(8)	141(8)	143(9)	146(18)	134(10)	10.70	0.058
T_{IR} [ms]	18(5)	20(6)	20(6)	19(6)	20(7)	24(6)	9.05	0.107
T_{EXT} [ms]	93(20)	87(15)	100(28)	98(21)	99(20)	109(9)	8.519	0.130

Subscripts: a - significant different from 400g ball; b - significant different from 600g Ball; c - significant different from 800g Ball; d - significant different from 1000g Ball; e - significant different from 1200g ball; f - significant different from javelin

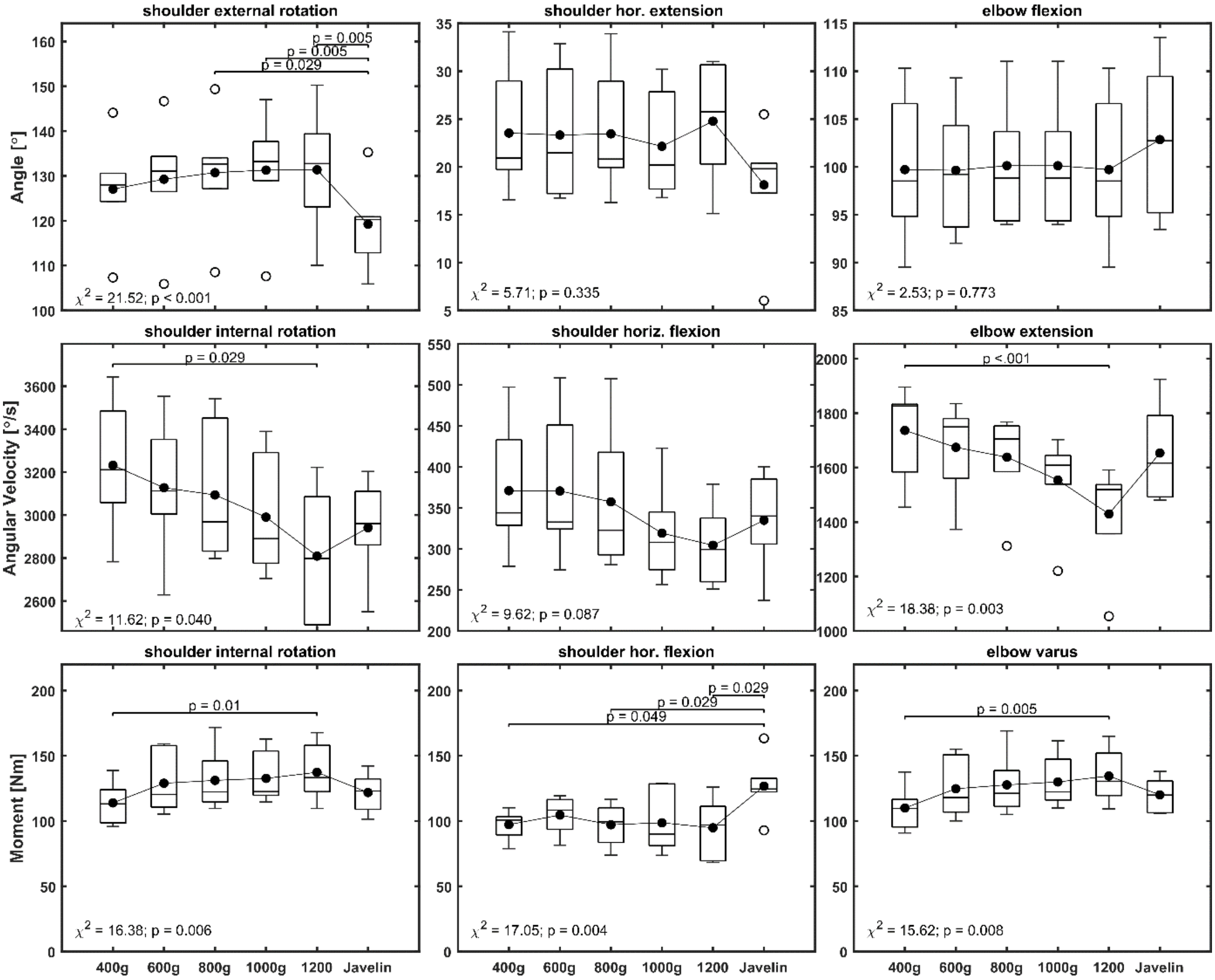

Figure 1: Boxplots of the different maximum values (see title of each plot) for joint angles (top row), joint angular velocity (middle row) and joint moment (bottom row). Additionally, the black dots mark the mean value, the statistics of the Friedmann-test (X^2) and the level of significance (p) for the omnibus test and post-hoc comparisons (only for significant differences) are added.

DISCUSSION: Th aims of the study were to (A) investigate the differences between ball and javelin throwing and (B) to examine the differences between throwing balls of different weights. As also shown for baseball and handball, the release velocity decreases with increasing mass of the throwing implement (Fleisig et al., 2017; van den Tillaar & Ettema, 2004). Compared to this, the release velocity of the javelin is located between 800 g and 1000 g ball. Although the athletes had longer run-up speeds using the javelin, the athletes were not able to generate higher release speeds compared to the ball with the same weight. It can therefore be assumed that either the shape of the implements is of interest, as the javelin must be accelerated along its longitudinal axis, or the athletes were not able to convert the higher run-up speed into a higher release speed. This circumstance cannot be conclusively clarified with the available data. However, if one looks at the data for the external rotation angle of the shoulder and the flexion angle of the elbow, there are differences between the javelin and the balls. Although, in case of the elbow these are not statistically relevant, it supports the assumption that the shape of the javelin influences technique in the main acceleration phase. Due to its length, the longitudinal axis of the javelin must be controlled and therefore the athletes adopt a slightly different body position to accelerate the javelin along its longitudinal axis.

Regarding the length of the delivery phase (T_1-T_2) and the main acceleration phase (T_2-T_3) and the onset of the elbow extension and shoulder internal rotation, no differences could be observed between the implements, although the javelin was thrown from a higher run-up speed. It can therefore be concluded that a temporal structure similar to that of the competition implement can be simulated with ball throws from shorter approaches/lower run-up speed.

Despite this equal temporal structure, a change in the joint angular velocities can be observed for the joint angular velocities of the shoulder and elbow joint. With increasing mass of the implement, the joint angular velocities decrease. However, significant differences can only be shown between the lightest and the heaviest ball. The angular velocities of the javelin are in the lower mid-range. It can therefore be assumed that lighter weights lead to higher angular velocities and thus to an improvement in movement control and -regulation and thus make an important contribution to achieving higher release speeds. If one looks at the joint moments, one can see that an increase in mass leads to an increase in moment. The horizontal flexion of the shoulder also shows that the javelin differs significantly from the balls. It must therefore be assumed that the driving mechanism of the javelin is subject to slightly different mechanical conditions than a ball, which could be attributed to the different shapes and the aforementioned differences in joint angles.

CONCLUSION: This study found that the assumptions previously made for the use of different implements were not entirely correct. It should be noted, for example, that there is no improvement in the “bow tension”. However, the equal drive time, combined with the tendency towards higher torques using heavier implements, suggest that muscles have to do more work and therefore strength training takes place under discipline-specific working conditions, which confirms the assumption that heavier implements can be used for special strength training. For the light implement, it can be stated that they represent a kinematic structure that comes close to the javelin throw. The angular velocities of the joints as well as the temporal structure are not different from the competition implement. However, the throws with the balls examined here have the advantage of achieving largely similar kinematics, although run-up speeds prevail. Such semi-specific throws therefore have the advantage of relieving the lower extremities, which are generally constrained to high loads in javelin throwing (Bartonietz, 2000), and can therefore also be used for preparation in larger volumes. This applies equally to heavy and light implements. However, it should be noted that the changes in body position, as determined in the study, do not have a negative influence on technique. It is therefore advisable to use throws with balls as an accompanying training tool in order to minimize negative transfer effects due to one-sided use.

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