Special motor program in the experienced dart players: support from kinematic data

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Abstract

Purpose: Especial advantage known as especial skills have come to mind specificity perspective in human motor control. The main objective was to explore the relative timing of throwing kinematics data in experienced daters so that it would provide examine specificity perspective.

Material: Seven experienced players executed 252 throws from seven distances with recording the kinematic data from the elbow.

Results: Data analysis was shown the especial relative timing in the most practiced distance in five from seven samples. We concluded that repetitive practices may lead to especial structure and kinematic pattern of limb that could interpret as a special motor program. The findings showed that as the massive workouts of experienced players have changed relative timing at kinematics levels, they show a special motor program in five samples and GMP in two samples. These findings indicate that the level of motor control not only cannot be GMP, but also may be a specific moto program.

Conclusions: *For the first time, findings of this study evident a specific motor program in the kinematic levels.* Findings did not support the GMP theory which creates a new view to schema theory.

Keywords: GMP, Relative timing, Special motor program, Especial skills, kinematic pattern

Introduction

One of main theories about the motor control structure that handle open loop action is motor program. It has a long history in the research literature [8-10]. The motor program notion has been challenged by many researchers [1, 16, 17]. Adams [1] advocate with the limited version of motor program that responsible for free feedback actions without any role in the remained movement. From this view, the CNS has a mechanism that manages the errors and feedback from the movement with perceptual traces as "program" in the close loop actions instead of the motor program. Some strong hypothesizes have made one modified motor program structure which have some extended features than originally did. Generalized motor program (GMP) had proposed by Schmidt [17]. He expresses that perceptual trace and motor program has two fundamental issues. The storage problem is first that refer to limited capacity of human CNS to store the many thousands of motor programs for per little movement. Second issue is the novelty problem that refer to some novel actions as unique version of the motor action which have not account for the motor program yet. GMPs are the suggested solution for these two issues that many researches have investigated its truth for invariant features (relative timing, relative force) and variant parameters (total time, total force) [16, 17]. They can manage the class of actions that have same constant feature which probably differ from another class by different invariant features.

One violation of the GMPs is the especial skills debate [5, 7]. These researches have reported the especial advantages creating by the massive amount of practices and thousands of repetitions in the one member of the actions' class in the basketball free throw [5, 6], baseball pitch [17], basketball jump shot in a favorite location [13], wheelchair basketball [4], archery [11-13]. New findings in the recent years have revealed a gap in the generalizability of the GMP which raise probability of co-occurrence of the MP and GMP or specificity and generality of motor program in the human motor control especially for rapid pre-programed actions. The question about the interpretation of the especial advantages in the experienced level of performance remained unclear. One of main hypothesizes about these especial advantages has been the there may train special motor program to explain different behavioral performance in one member of the class of the GMP. Breslin et al. [3] has searched for special coordination pattern in the elite basketball players. Participants performed free throws from the 4.5 meters from the basket and other locations. Breslin et al. [3] record also the kinematic pattern of the throwing hand for relative timing analysis. Their findings did not support the different coordination pattern (GMP) in most practiced distances (fit line) than other locations. This research [3] was only research in which special motor program is explored in the kinematic level. The present paper tries to provide more evidence about any effect of the massive amount of practice on the relative timing of the skilled players. We expect new timing structure in one member of the class of actions rather than other members of that in experienced dart players. It seems dart is more fine skill in which experienced players perform dart throw with the more accurate target. This skill also performs with the constant way than basketball free throw with sometime variable practice. These variable make dart throw as more valid task of explore the especial effect in the especial skills issue. We have skipped behavioral data so we have tested relative timing of throwing pattern in kinematic level to search for especial motor program in the 2.37 meter from the target that has massive practice than other nearer and further distances. We also compare elbow angle, angular velocity and angular acceleration in

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the most practiced distance (2.37 m) and other distances to prepare more details about the especial motor program hypothesis.

Material and methods

Participants

The samples included eight experienced dart players who had a variety of experience from minimum of 1 years to a maximum of 11 years at Darts (M = 6.38, SD = 2.78). In similar researches, a number of examples have been used in the nearby range [3, 5, 6, 17]. All players' age ranges were between 18 and 37 years old (M = 30.37, SD = 7.19). All of them had complete vision and had inclusion criteria for research. Players must have the following conditions to enter and participate in the final experiment:

1. Have at least 1 years of experience in darts [2] with regular dart practice with Triple 20.
2. The main goal of the players in practice and competition was triple 20.
3. All participants were right handed.
4. Standing position has been 45 degrees over the most years of practice and competition.

Procedure

First, we measured 2.37 from the center of the dart on the ground in the distance from the dart throw according to the world dart federation rules. Then the players were asked to sit on the chair to prepare for the installation of the markers. Markers were installed based on the Helen Hayes marker system. Before placement, the marker position was detected in the joint by touch, and then the marker was installed to measure the external and internal elbow [10]. Two markers were installed in the players' right hand. The kinematic variables considered in this study are the time difference between the landmarks (before peak, first peak and second peak) in the acceleration, velocity and angle curve of the elbow [3]. Before the experiment, the cameras were set on throwing zone. After calibrating the cameras, the cameras were checked again after each set (seven distance completed) in order to increase the accuracy of the kinematic data; then the cameras were calibrated again if necessary. After the markers were installed on the designated anatomical distances, the players were asked to take a few trials throws so that made players fit with the markers' adhesive. They were also asked to announce the start of the experiment with their full readiness. After the announcement of the player, the experiment began. The recording process was such that the start time of cameras was open (open time) in order to recall neutral throw. It means that the time would begin without the player's knowledge in which, when he was ready to start the throw was started recording by the trigger (lab operator).

252 Dart throws were executed in three sets by each sample from the standard distance (middle distance underline) which experience massive amount of practice and 6 other distances (1.44, 1.75, 0.26, 2.37, 2.68, 2.99 and 3.30 m) from the target. The players executed the throws in the form of 3 sets. A total of 36 throws were executed in total of each distance. The players completed 12 throws at each distance and then went to the next (except two participants with 6 throws in each distance). Distances were numbered 1 to 7 from near to far one. Setting distances and their markings were done in such a way that distances were not recognizable in order to decrease any deliberate intention to throw from standard distance (2.37 m). To change distances, the board was displaced over these distances instead of moving players who performed their throws from fixed point without their own displacement. The dart board and its foundation were displaced in distances with the fingers cue (showing distance numbers) by experimenter 1 so that the players only saw the board displacement without knowing the distance. In order to reduce the order effect, the distances order for each sample was personally designed which was different for each sample in per set. The throws were performed by the personal pattern of the players and they were told that they would not restrict their throws. Players were asked to report any restrictions on markers during throws to correct it. After completing seven random distances (one set), the players were rested for five minutes and then performed the second set in the same way with another random order. Players only received visual feedback with providing score information. There was no one in the experiment room other than the darts player and 3 experimenters (Lab Operator, Score Record and Board Setting).

The experiment was done in the TAK Laboratory in Mashhad, Iran. The personal darts of the players were used, all of which were standard darts that used in their practices and competitions. The task was darting throw because of the greater execution stability, which give more balance and less variability in performance rather than basketball free throw [3, 5, 6, 12]. QTM software and eight Qualysis cameras with marker based and 3D method were used. Double-sided adhesives were applied to install markers on elbow that were 1 cm in diameter.

Data Processing

First, the kinematic data were digitized in which marker is labeled and each throw is extracted from the separate data file so that the time windows for each throw were specified which the data was exported in each time window (figure 1). The time window was from the moment when the initial movement of the hand to the back has begun, until the darts were thrown and the hand has begun to move downward. Then 4 throws from all 12 throws were selected as middle throw in per round (each 3 throw is 1 round) in order to decrease any fatigue or warm up effects in initial throw in each round. It means that the 2, 5, 8, 11th throws were chosen to process at each distance and 2, 3, 4, 5th throws in two samples with 6 throws in each distance so that first and last throws were ignored. Before processing, seven distances were set in the original order in the new folders. A low pass butter worth filter with 6 orders were applied so the mean and normal values were extracted as the elbow angle, angular velocity and angular acceleration of the elbow (figure 3).

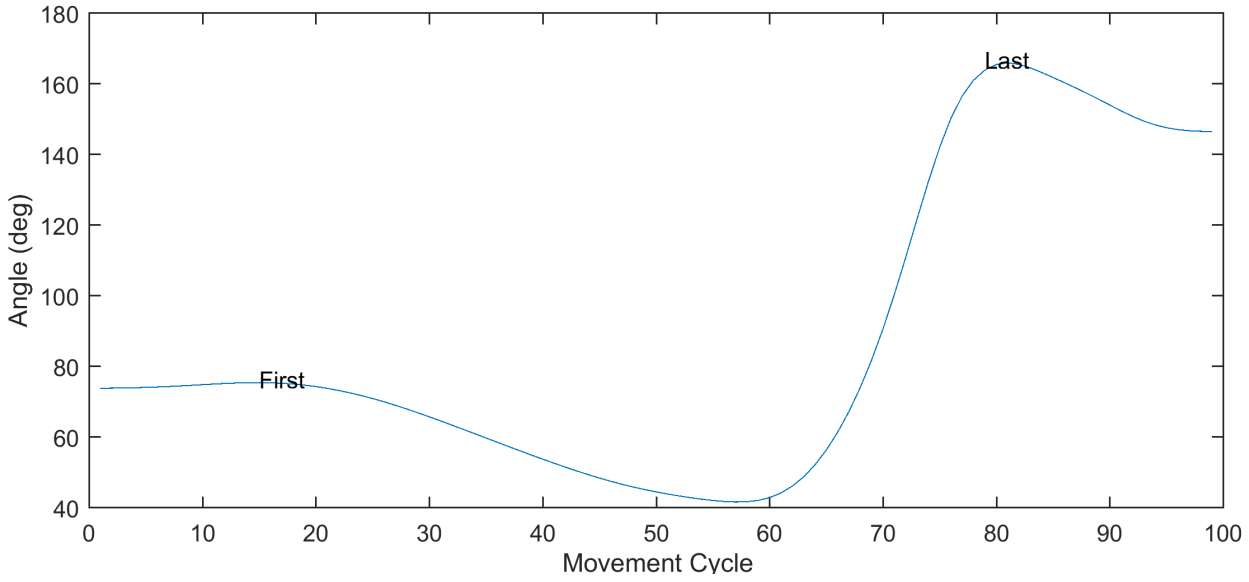

Figure 1. Time window sample for each throw that used to extract kinematic variables and relative timing landmarks according to the first peak and the last peak of the throw curve

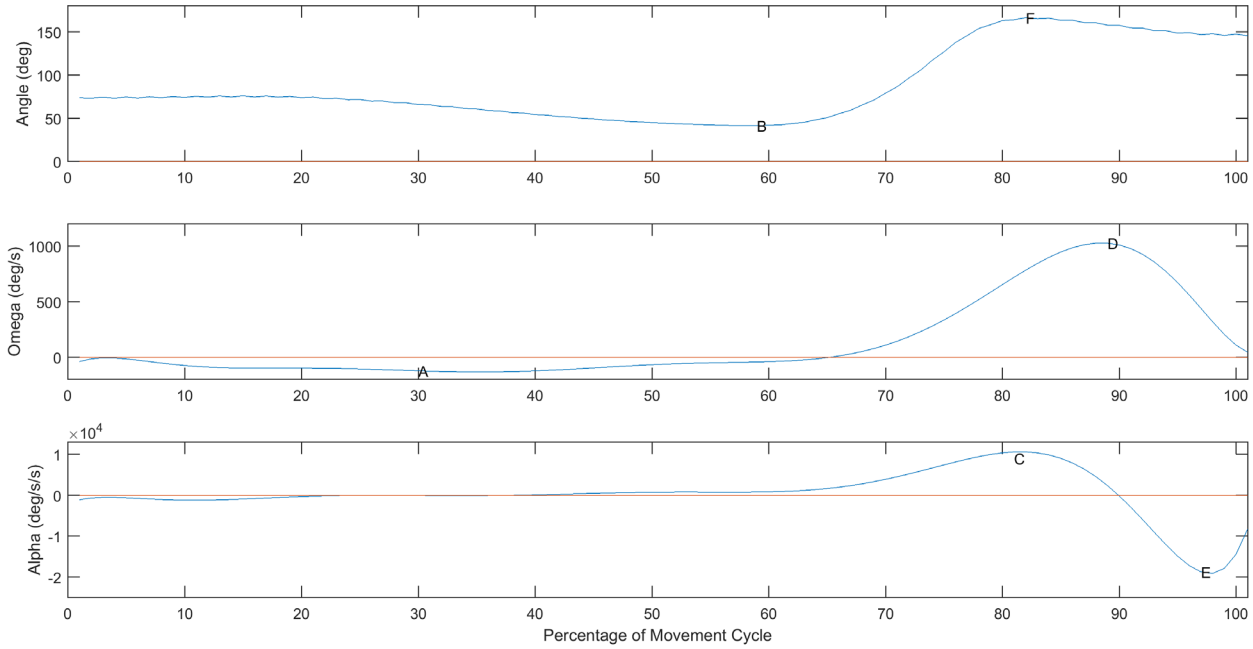

Figure 2. From top to down, elbow angle, angular acceleration and angular velocity of elbow in which peak and land of each plot determined landmarks A-F.

Kinematic landmarks A to E were also extracted from the elbow angle, velocity and acceleration time series data (figure 2) that normalized to 101 points. Obtained data, then used for statistical analysis.

Statistical analysis. Shapiro-Wilk test was used to test the normality of kinematic data. To compare the kinematic landmarks and variables in the distant 4 and 6 other distances U Man-Whitney or analysis of variance were used based on the normality results. LSD test was applied as tracking measures in normal distributions.

Results

We used individual data for statistical analysis to decrease any bias in the relative timing and kinematic analysis. Before any analysis at a significant level of 0.05. All landmarks data were used after they normalized to 100 points to synchronize all samples with variable time series.

In sample A, to compare kinematic variables at different distance Mann-Whitney test was used. The results of this test have shown in table 1. These findings showed a significant difference in the elbow angles between 1 and highly practiced distance (4) distance. Similarly, there is a significant difference in the elbow angular velocity between 4 and the 3 and 5 distances. In the elbow angular acceleration, there is a significant difference between 4 and 1, 2 and 7 distances. LSD test was shown there were also no significant differences

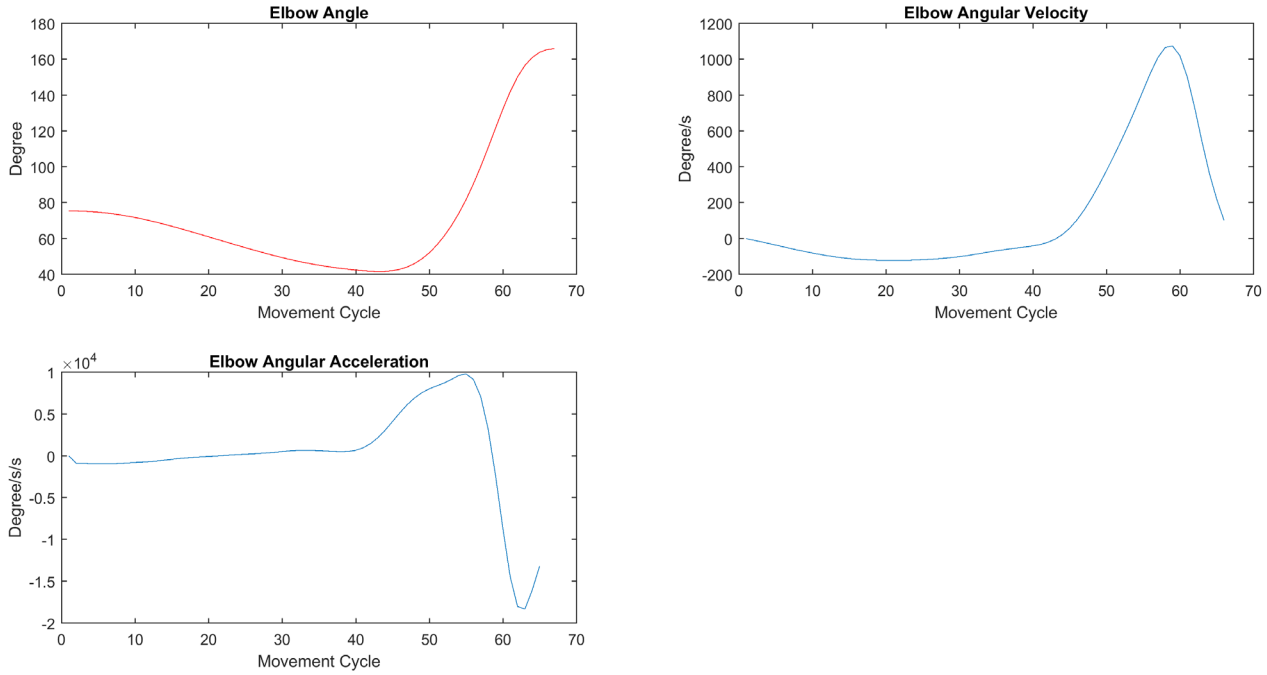

Figure 3. Respectively, the elbow angle curves, angular acceleration and angular velocity of the elbow marker. Landmarks A to E are calculated according to the first landing and the last peak in each curve (Breslin et al, 2012)

between the highly practiced distance and six other distances in the relative timing landmarks B, A and F. But the D and C landmarks were shown different in the distance 4 and six other distances, which relate to the peak of the angles of velocity and angular acceleration

In sample B, to compare kinematic variables at different distance, LSD test was used (see table 1) which showed there was significant difference between the three kinematic variables in the seven distances. Therefore, in order to examine the extent of the variation of the kinematic relative timing landmarks in seven distances, the Mann-Whitney test was used. The results of Mann-Whitney test show that there is significant difference between distance 4 and 7 in the E and D landmarks. However, there were no significant differences between the mass practiced distance and six other distances in remained landmarks of relative timing.

In sample C, the results of ANOVA in table 1 indicate the significant difference between the distance 4 where the massed practiced skills and the other six distances at elbow angular velocity and the angular acceleration but not observed in elbow angle. The U-Man-Whitney test was used to determine the difference between the kinematic landmarks of relative timing in seven distances. The results showed that there were significant differences between the distance 4 and 3 in the B, D, C landmarks and between distance 4 and two in Landmark A, respectively but there were not any significant differences in Landmark E and F.

In sample D, the results of the U-Mann-Whitney test confirmed that greatest difference between the distance 4 and all other six distances exist at the elbow angular velocity bot not observed in the angular acceleration and the elbow angle. The LSD test was shown that there is a significant difference between the distance 4 and the distance 2, 5 and 6 in the landmark D. In Landmark A and E, there is a significant difference between the distance 4 and 6. There is a significant difference in the landmark C between distance 4 with further distances 5, 6 and 7. But in Landmark E and F there is no any significant difference.

In sample E, to compare the mean kinematic variables of distance 4, the Mann-Whitney test was used. The results of this test are shown in Table 1. These findings showed the angular velocity of the elbow has significant difference between 4 and 3, 6 7 distances that means and confirms these special changes. In order to examine the specificity of the kinematic relative timing landmarks in seven distances, U Mann-Whitney test results showed that there is a significant difference between the distance 4 and the distance 6 and 7 in the relative timing landmark D. There was a significant difference in landmark A between distance 4 and distance 3 and 5. In landmark C, there was a significant difference between distance 4 with distances of 3, 5, 6 and 7. But in Landmark B, E and F, there was not seen.

In sample F, the results of ANOVA test showed that there is a significant difference between distances in angular velocity and acceleration but not in elbow angle. For further examination, the LSD follow-up test showed that there is significant difference in the angular velocity between distance 4 and 1 also in the angular acceleration between 4 and 3, 5 and 7. The ANOVA was used to determine the difference between the kinematic relative timing landmarks in 7 distances. The results showed that there was significant difference between distance 4 and 3, 6 and 7 distance in D landmark. In the C landmark, there is significant difference between the distance 4 with all distances except the distance of 5. However, there is no

significant difference in landmark A between distances. In landmarks E and F, there were only significant differences between 4 and 3 distance.

In sample G, to compare mean kinematic variables with a distance 4, the U-Mann-Whitney test is used. The results indicated that there was difference between distance 4 where the mass practices were done, and distances away from the target (6 and 7) at the angular velocity of the elbow but not observed in the elbow angle and angular acceleration. About relative timing landmarks, the results of the U-Mann-Whitney test showed that there was only a significant difference between the distance 4 and the 6, 7 distance.

In total, at the angular velocity, six samples have a minimum of three distances which showed significant differences with distance 4. In the case of angular acceleration, three of seven samples have had a minimum of three distances which indicated significant differences with a distant 4. At the elbow angle, only one of the three samples showed a significant difference with the distance 4. Landmarks of relative timing analysis showed that there was significant difference between the relative timing of landmarks A, C, and D at the distance 4 and at least three other distances in seven samples. Also, in landmark B, except for two distances in sample A and one distance in the sample F, did not show the difference between

Table 1. Differences between three kinematic variables and relative timing landmarks A-F of distance 4 and other 6 distances in all samples calculated by ANOVA and U Man Whitney tests which selected based on the normality test results. Significant value is shown at 0.05 level with bold numbers.

	Distances	Angle	Velocity	Acceleration	Landmarks					
					A	B	C	D	E	F
	1 & 4	.003	.225	**.007**	.344	.236	.067	**.030**	.073	.795
	2 & 4	.525	.488	**.001**	.792	.452	**.045**	**.014**	.126	.729
Sample	3 & 4	.853	**.001**	.853	.593	.926	**.034**	.245	.375	.926
A	5 & 4	.564	**.033**	.248	.331	.435	.127	**.004**	**.008**	.885
	6 & 4	.149	.273	.184	.065	.665	**.011**	**.001**	**.003**	.272
	7 & 4	.073	.083	**.021**	.332	.840	**000**	**.000**	**.000**	.452
	1 & 4	**.014**	.081	.204	.447	.869	.619	.741	.786	.817
	2 & 4	**.000**	**.004**	.061	.076	.972	.089	.273	.197	.169
Sample	3 & 4	**.028**	**.002**	.787	.229	.290	.869	.354	.459	.596
B	5 & 4	.271	**.011**	.874	.947	1.000	.506	.096	.305	.869
	6 & 4	.074	.262	.417	.572	.168	.417	.112	.386	.573
	7 & 4	.271	**.018**	**.019**	.624	.307	.102	**.003**	**.019**	1.000
	1 & 4	.341	.030	.001	**.024**	.685	.559	.952	.112	.354
	2 & 4	.276	.353	**.027**	.060	.728	.170	.584	.615	.469
Sample	3 & 4	.203	.003	.000	**.001**	.072	.220	**.025**	.148	.272
C	5 & 4	.671	.984	.876	.370	**.031**	.679	.731	.356	.729
	6 & 4	.105	**.043**	.830	.078	**.045**	**.003**	**.010**	.148	.340
	7 & 4	.764	.019	.104	**.037**	.399	**.022**	.075	.148	.525
	1 & 4	.644	.742	.356	.055	.426	.507	.061	.617	.175
	2 & 4	.821	.226	.290	.306	.622	.341	**.046**	.199	.052
Sample	3 & 4	1.000	.545	.762	.595	.649	.494	.201	.789	.699
D	5 & 4	.778	**.049**	.622	.091	.244	**.005**	**.009**	.186	.287
	6 & 4	.895	**.002**	.262	**.005**	.221	**.004**	**.002**	**.016**	.067
	7 & 4	.692	**.025**	.644	.843	.186	**.021**	.125	.286	.216
	1 & 4	.644	.086	**.048**	1.000	.354	.186	.648	.361	.303
	2 & 4	.424	.622	.951	.805	.757	.697	.711	.338	.557
Sample	3 & 4	.075	**.035**	.947	**.024**	.209	**.014**	.271	.361	.253
E	5 & 4	.951	.538	.712	**030**	.975	**.022**	.077	.338	.640
	6 & 4	.386	**.003**	.603	.056	.272	**.001**	**.044**	.952	.930
	7 & 4	.692	**.048**	.356	.551	.289	**.001**	**.022**	.361	.791
	1 & 4	.363	**.046**	.282	.409	.728	**.000**	.109	.775	.754
	2 & 4	.757	.185	.270	.970	.178	**.000**	.109	.476	.063
Sample	3 & 4	.866	.151	**.043**	.476	.588	**.009**	**.022**	**.049**	**.034**
F	5 & 4	.896	.227	**.006**	.735	.166	.073	.109	.228	.227
	6 & 4	.127	.154	.318	.070	.215	**.005**	**.035**	.258	.095
	7 & 4	.251	.184	**.039**	.074	**.025**	**.000**	**.003**	.137	.225
	1 & 4	.250	.450	.123	.193	.339	.612	.535	.747	.090
	2 & 4	.577	.670	.108	.363	.974	.589	.520	.933	.767
Sample	3 & 4	.074	.176	.460	.319	.689	.975	.874	.174	.951
G	5 & 4	.424	.806	.279	.877	.116	.161	.724	.872	.146
	6 & 4	.922	**.033**	.140	**.016**	.391	.785	.731	.282	.292
	7 & 4	.818	**.003**	.951	**.010**	.340	.464	1.000	.590	.531

the distance 4 and the other distances. The landmark E analysis also showed that there was significant difference between the distance 4 in sample A, C, D, E and F. In the landmark F there is only a significant difference between distance 4 and others in sample F.

Discussion

The main objective of the experiment was investigating the existence of "special motor program" in the 2.37 meters from target that have executed massive amount of practice by experienced dart players. The results of kinematic data support the existence of a specific structure that may be separate from other locations in which data mainly support the main role of angular velocity of elbow and less in the angular acceleration with different qualifications at the kinematic level that may have been created through high repetitions in the 4th distance. These findings are supported in part the claim that a massive exercise at a member of a class of actions or movements (dart throw) can lead to special advantages which separate that member from the others. This especial advantage can cause to form new motor program at a distance 4. In this regard, Breslin et al. [2] examined the hypothesis of the special motor program (new coordination pattern) in experienced basketball players who have done massive amount of practices on 4.5 meters from the basket. They examined the difference between coordination patterns of the highly practiced distance and other near and far distances by one foot. The findings of this research did not support this hypothesis so that there is no significant difference in the 4.5 meters' distance away from the surrounding area.

We also consider relative timing of the dart throws was extracted from the data related to angle, angular velocity and acceleration of elbow. Except sample B (with lowest experience) and sample G, other samples appear to have a specific relative timing at distance 4. This hypothesis is confirmed more strongly in samples A, E and F, and it is more likely that specific coordination and kinematic pattern can be determined from the mass exercises at a distance 4. The results showed that at least, there is a specific relative timing in the A, C and D landmarks at a distant 4 in all samples (except to two samples). These findings clearly support the existence a specific motor program at 2.37 meters in five samples and suggests that massive amount of repetitions in experienced darters can change the structure of the GMP and be visible at the kinematic level. Breslin et al. [2] conducted this experiment on experienced basketball players. They set five distances and five landmarks for determining the relative timing of the throw patterns. The final results of this analysis showed that there is similarity between the landmarks in a distance 4 (highly practiced) from the surrounding distances. Breslin et al reported that the at least kinematic level may does not create a specific motor program for experienced dart players in mass practiced distance than all distances are implemented as a class of movement by same GMP management. However, the results do not support the results of Breslin et al. [2] which confirms the hypothesis that there may be special motor program in experienced Dart players at a distance of 2.37 meters, which separates GMP from another except to two sample who one of them had most less experience rather than other five samples.

Especial motor program instead of GMP in control of skillful actions?

The results of this study flicker the probability that it may with GMP background, with increasing the skill level (or repetitions) in actions and sensorimotor tasks, GMP upgraded to especial type of that. This hypothesis is highly probable that GMP structure probably could not generalize as Schmidt et al. [14, 15] and other research literature reported. By increasing skill levels and repetitions, this structure is allocated to a specific neuronal element in a mass practiced distance, more related with relative timing of the kinematics components. At higher levels of skill and in more repetitions (many years of experience), it may other structures appear to be the management of the upper-shoulder throwing skills that have a higher upgraded range and possibly up to 90 cm ahead support. But whether these structures can be managed right and left with a range of 90 cm, this is a question but this is possible! It is also likely that these specific structures with limited generalizability will be created for other skills with high repetitions and experience in the homework with targeting skills. These structures, in the event of recurrence, create storage and novelty problems again which had been two main reasons for suggesting the generalize motor program instead of separate motor program for many of human movement tasks.

Conclusion:

The purpose of this study was to investigate the effect of mass training on the kinematic level of GMP. The findings showed that as the massive workouts of experienced players have changed relative timing at kinematics levels, they show a special motor program in five samples and GMP in two samples. These findings indicate that the level of motor control not only cannot be GMP, but also may be a specific moto program. For the first time, findings of this study evident a specific motor program in the kinematic levels. Future research could investigate other determinant of the GMP in different task contexts.

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Conflict of interests

The authors state that there is no conflict of interest.

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