Original Article

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Visual constraints and swing timing in softball batting: pitcher vs. pitching machine

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Abstract

When players practice batting against a pitching machine, there are some visual constraints that can affect the movement behaviour of the batter due to the absence of visual information sources that are available in competition performance (pitcher motion). This study sought to compare the timing of softball swing phases whilst batting against a pitcher and a pitching machine. Semi-experienced batters were recorded using a high-speed camera (200 fps) hitting balls (same pitch type) when batting against a pitcher and a pitching machine. Results showed significant differences in specific phases of swing timing under both conditions and each player was affected individually, mostly in the movement initiation (heel of the front leg) and duration of leg on – forward swing initiation. Practice task constraints that removed information sources were shown to have affected batters in specific phases of their swing. Therefore, pitching machines should be used wisely, and coaches should be aware of issues of how the use of pitching machines can affect the softball swing, even with lower level softball players. Furthermore, analysing participants as a group, as opposed to assessing individual differences within the group, can lead to inaccurate results and interpretations individual player's motor responses and behaviour can be affected in different ways.

Keywords: perception; visual cues; anticipation; perception-action coupling

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INTRODUCTION

Batting is an important offensive skill in softball. The ball can travel towards the batter in top male competitions around 130 km/h or in female competitions around 115 km/h respectively [1]. In female competitions, the pitching distance is 13 meters and the flight time from the pitcher to the batter can be less than 0.5 s. To hit the pitched ball requires not only good physical conditioning prerequisites (such as dynamic strength etc.) to enable production of power to effectively intercept the ball with a bat, but also with anticipation of timing and placement of bat to hit the ball [2]. It is the timing of a swing with a bat to the expected ball contact point under the standard conditions defined by the softball rules. Similar movement tasks are required by batters in cricket and baseball, as well as in tennis where the receiving player is playing against an opponent [3].

Players and coaches use drills to practice the learning and development of batting skill. In addition to hitting standard live softball pitching (real situation), drills are used in various training exercises, for example, hitting from a batting tee or using a pitching machine. A pitching machine allows the hitting of a ball projected at high speed with a relatively high accuracy of pitch position to the strike zone. Introduction of pitch counts to avoid overloading the pitcher`s musculoskeletal system is another reason for the use of pitching machines is they provide the opportunity to receive a high quantity and quality of pitches within a designated training time. Werner et al. [1] reported that joint loads at the shoulder in softball pitching are similar to professional baseball pitching, which suggests that these athletes could risk overuse injuries if pitch loads are not monitored. Furthermore, using pitch counts in youth categories can decrease injury rates [4]. However, the use of pitching machines can affect movement coordination [5] as it results in batters converging on non-specifying variables [6]. This delays attunement to specifying variables [7] and suggests the use of pitching machines in batting training should be limited [8].

The removal of critical information sources (batting against a pitching machine) at specific developmental stages (cognitive and motor skill) could impede learning that results in unintended changes to the coordination of actions. Therefore batters should be provided with opportunities to pick up specific variables available (face a pitcher) to support performance in competitive context [5]. In other words, if the batters cannot see the pre-release (advance) cues that present specific pitcher kinematics (e.g. upper limb movement and positioning), the batter cannot anticipate, the ball release moment, but rather will be guessing the moment ball release occurs. As this valuable visual information is not available whilst using the pitching machine. Pinder et al. [5] suggested that use of a pitching machine changes not only available informational variables until ball release, but also the nature of delivery after ball release (essential pre-ball flight information are missing). The batters set-up their gaze at the point on the anticipated trajectory of the ball before release and reduce the quality of interception compared to pitcher/bowler [5,9,10].

Previous research has shown that swing timing is different while facing the pitching machine in various sports. Renshaw et al. [10] found differences in initiation of backswing in cricket. Batters who used a bowling machine initiated the backswing 100 ms earlier compared to when facing a bowler. Similar differences were found in initiation of the downswing, which occurred 320 ms after ball release from a bowling machine and 410 ms after ball release from a bowler. Praveckova et al. [11] compared swing timing in baseball while batting and reported that the pitching machine affected swing timing compared to the pitcher, with the forward swing duration significantly (80 ms) longer in the case of the pitching machine.

Differences in the duration of the various phases in the specific hitting conditions can be caused by absence of visual information sources from a pitcher's motion that is necessary to inform a batter's motor response [10,11]. One of the stages of constructing information coupling is to attract attention to key information sources [12]. The design goal of training should be that the batter hits the ball with a similar timing of each phase that is representative of the performance environment. Removal of crucial information sources can affect swing timing and motor learning process. Pinder et al. [13] proposed methods of how to optimize developmental programmes in fast ball games and situations, in which a ball machine can be used. This suggest the use of pitching machines should differ according to the needs of different skill groups (the pitching machine is usually used very rarely at the very top softball level) and the pitching machine should be used as a supplement (not a replacement) to the "live" pitcher/bowler in the acquisition of batting actions.

Most studies examining the effect of training against a pitching machine has focused on the top-level athletes. The pitching machine is not employed very often in elite level softball, however in lesser-skilled or junior levels it is used more often in practice sessions [14].

The aim of this study is to compare the timing of the softball swing phases whilst batting against a pitcher and a pitching machine. In this study we also set out to assess the effect of pitching machines on motor responses in lesser-skilled athletes, where the pitching machine is used often in practice sessions. Previous research in this area has usually focused on group analyses and comparisons. In this study we will examine task constraints and motor behaviour at the individual level in an attempt to highlight that swing differences occur at the individual level and this is a more accurate measure of timing differences.

MATERIALS AND METHODS

Participants

Participants were 6 female players [15] competing in the second highest division in the Czech Republic (22.3 ± 3.2 years; 62.7 ± 2.6 kg; 171.2 ± 3.1 cm). Four were right-handed and two were left-handed batters. All participants played competitive softball for 3-5 years. Softball swing mechanics corresponded, despite individual differences in techniques, to the generally known and used techniques [16]. None of the test participants were affected by unfavourable health or fatigue and the same test conditions were created for all players.

Procedures

This study took place on a standard competition softball field. All participants undertook a standard warm-up including batting from the tee and lower toss. After that they faced the pitcher first and then the pitching machine (Jugs BP2). In each condition (pitcher and pitching machine) the participants received 3 practice trials before the testing trials commenced [3]. The pitcher/pitching machine executed the pitches from same distance as in a competitive match (13 m from the home base). The type of pitches was fastball. One pitcher was used for all the participants. The pitcher was a very experienced softball player (35 years old with 20 years of playing experience as a pitcher) and pitch the balls with stable (79.3 ± 3.2 km/h) to the strike zoneAs mentioned above, the participants hit 10 balls pitched by a pitcher first and then proceeded to pitching machine condition and hit 10 balls from the pitching machine. While hitting the balls from the pitching machine, the participants received a signal approx. 2 s before the ball release. There was a 5-minute break between the pitcher and pitching machine condition. The speed was checked by a radar (Stalker Pro II). The pitching machine speed was set to the same speed as the pitcher (77.2 ± 2.3 km/h).

The dependent variables are the duration of selected phases of the swing [2,11], which included: (1) movement initiation: start of the weight transfer phase - the moment when the heel of the front leg interrupted the contact with the ground (the batter started the timing step); (2) duration of the timing step: time between movement initiation and the end of the timing step (the moment when the batter's front leg re-touched the ground); (3) Lag before the forward swing – time between the end of the timing step and the moment when the rear elbow initiated to move forward towards the ball; and (4) duration of the forward swing phase – time between the rear elbow forward movement initiation and bat-ball contact. The time zero on timeline means the moment when the ball is released from the pitching machine or from the hand by the pitcher. Basler GeniCam piA640-210gc high-speed camera with a frame rate 200 fps was used to record testing sessions. The video camera was positioned 10 m from the home plate, facing the batter, so that the action of the pitcher/pitching machine (including the ball release) and batter's action was in the camera frame (figure 1 shows the experimental set-up as was previously done [2,3,11,17].

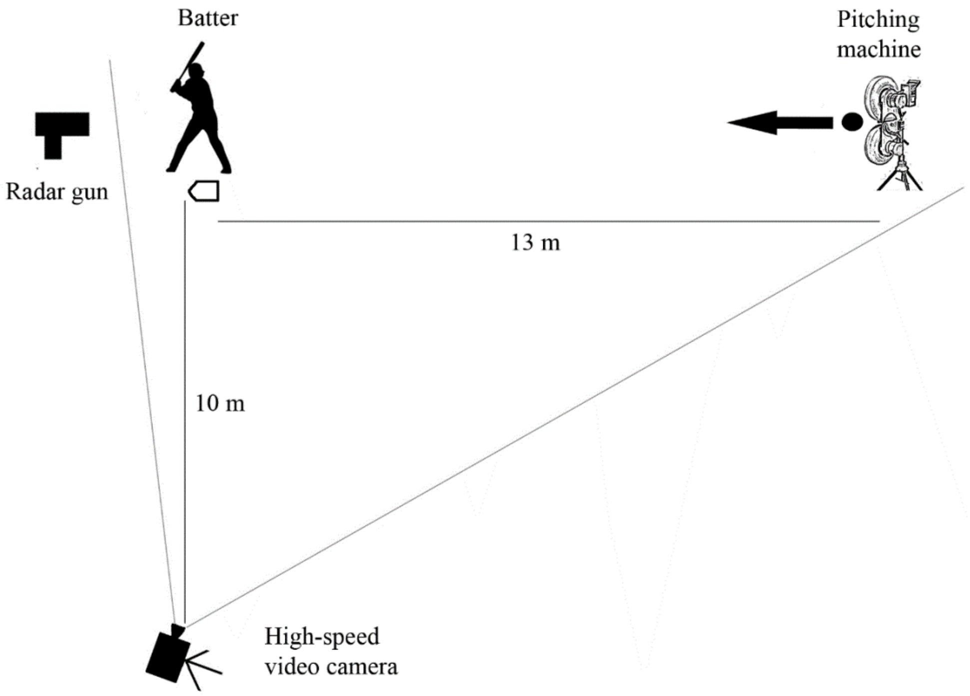

Figure 1. Experimental set-up.

Data analyses

Recordings from the video camera have been evaluated using the Dartfish 7 Team Pro software. The participants were recorded for 10 trials s against the pitcher and in 10 trials against the pitching machine. Data was analysed using descriptive statistics (including mean, standard deviation, mean difference) and paired samples T-test in SPSS 17.0 software. Using data from a previous study [10], an a-priori power analysis showed a power of 0.91 based on an effect size of 2.0, alpha level of 0.05, and a matched-pairs sample size of 5. In this type of anticipation and visual perception research, even small sample size is valuable and arguments for small sample size are defended by Müller et al. [15] and similar visual perception studies in sport games with sample size 5 [18] or 7 [19] exist and are beneficial to this research field. Effect sizes (Cohen's d) were calculated and can be interpreted as small (0.20 to 0.49), medium (0.50 to 0.79), and large ($d \geq 0.80$) [20].

Ethics

The study was approved by the Ethics Committee at the Faculty of Physical Education and Sport, at the University in accordance with the Declaration of Helsinki. All participants were informed of risks and benefits of the study and provided written informed consent prior to participating.

RESULTS

Batters results were calculated for each participant individually (Table 1). Statistical difference in specific phases of batters' swing affected by the pitching machine was found in every batter, except batter 4. T-tests showed a significant difference in the movement initiation of batter 1 $t(9)= -2.34$, $p = 0.04$, $d = 0.89$; and batter 3 $t(9)= -12.46$, $p < 0.001$, $d = 2.26$. Both batters initiated their movement later in the case of the pitching machine. Batter 6 had a significantly shorter lag before the forward swing $t(9)= 3.55$, $p < 0.01$, $d = 0.75$, but had a significantly longer forward swing duration when she faced the pitching machine $t(9)= -3.47$, $p < 0.01$, $d = 1.32$. On the other hand, batter 2 and 5 reached a significantly longer lag before the forward swing in the pitching machine condition $t(9)= -6.51$, $p < 0.001$, $d = 2.23$ (batter 2); $t(9)= -6.17$, $p < 0.001$, $d = 1.85$ (batter 5). Effect size (Cohen d) revealed a large effect in all the significant differences mentioned above (except for the medium effect of batter's

6 lag before the forward swing) plus a large effect of longer timing step duration (batter 1, three years involved in softball) when facing the pitching machine compared to the pitcher. Standard deviation and confidence intervals showed that batter 4 and 6 had higher variability of the movement initiation or leg off – leg on phase between the trials (interestingly, batter 4 had five years of softball experience). Only medium effect size was revealed in leg off–leg on duration between the conditions of batter 4. All other batters were involved in competitive softball for 4 years, except of three years of batter 3. Descriptive statistics and other effect sizes are detailed in Table 1.

Group level data analysis (similar to [2,3,10,11,21,22]) is presented in Table 2. T-tests showed a significant difference of the forward swing duration, which was longer when batters faced the pitching machine (M = 0.154 ± 0.019) compared to the pitcher (M = 0.142 ± 0.017) t(5)= -3.83, p = 0.012. This is supported by medium effect size (*d* = 0.67). Otherwise no significant difference or effect size was found in other observed variables. The effect of the pitching machine individually affected the participants' swing timing and its specific phases.

Table 1. Swing timing against pitcher and pitching machine conditions; comparison of individual batters.

Batter	Indicator	Pitcher Mean ± SD	Pitching Machine Mean ± SD	MD	t-test	p	Cohen *d*
1	Movement initiation (Leg off) (s)	*0.103±0.038	0.154±0.072	-0.051	-2.338	0.044	0.886
	Leg off – Leg on (s)	0.246±0.041	0.292±0.065	-0.046	-1.877	0.093	0.846
	Leg on – Forward swing initiation (s)	0.068±0.020	0.059±0.044	0.009	0.660	0.526	0.263
	Forward swing duration (s)	0.131±0.009	0.138±0.014	-0.008	-1.649	0.134	0.652
2	Movement initiation (Leg off) (s)	0.022±0.032	0.060±0.088	-0.037	-1.324	0.218	0.573
	Leg off – Leg on (s)	0.321±0.054	0.278±0.062	0.043	2.156	0.059	0.740
	Leg on – Forward swing initiation (s)	†0.091±0.050	0.198±0.045	-0.107	-6.508	<0.001	2.225
	Forward swing duration (s)	0.131±0.017	0.142±0.031	-0.011	-1.016	0.336	0.440
3	Movement initiation (Leg off) (s)	†0.055±0.026	0.200±0.033	-0.146	-12.460	<0.001	4.881
	Leg off – Leg on (s)	0.206±0.046	0.200±0.024	0.011	0.557	0.591	0.163
	Leg on – Forward swing initiation (s)	0.117±0.059	0.090±0.050	0.028	1.278	0.233	0.493
	Forward swing duration (s)	0.171±0.021	0.177±0.020	-0.005	-0.521	0.615	0.293
4	Movement initiation (Leg off) (s)	-0.233±0.238	-0.266±0.225	0.033	0.277	0.788	0.142
	Leg off – Leg on (s)	0.529±0.193	0.657±0.239	-0.128	-1.234	0.248	0.590
	Leg on – Forward swing initiation (s)	0.104±0.058	0.085±0.056	0.019	0.688	0.508	0.333
	Forward swing duration (s)	0.134±0.016	0.145±0.022	-0.011	-1.289	0.230	0.572
5	Movement initiation (Leg off) (s)	0.032±0.021	0.026±0.032	0.006	0.490	0.636	0.222
	Leg off – Leg on (s)	0.313±0.051	0.272±0.060	0.042	2.134	0.062	0.736
	Leg on – Forward swing initiation (s)	†0.084±0.055	0.185±0.054	-0.101	-6.173	<0.001	1.853
	Forward swing duration (s)	0.132±0.020	0.141±0.029	-0.009	-0.816	0.435	0.361
6	Movement initiation (Leg off) (s)	-0.169±0.358	0.066±0.089	-0.235	-1.929	0.086	0.901
	Leg off – Leg on (s)	0.489±0.359	0.369±0.095	0.120	0.982	0.352	0.457
	Leg on – Forward swing initiation (s)	*0.077±0.046	0.046±0.036	0.032	3.546	0.006	0.751
	Forward swing duration (s)	*0.151±0.021	0.178±0.020	-0.027	-3.474	0.007	1.316

MD - Mean Difference; SD – Standard deviation; Significantly different than Pitching Machine ($p < 0.05$)*; ($p < 0.001$) †.

Table 2. Overall swing timing; comparison of pitcher and pitching machine.

Indicator	Pitcher Mean ± SD	Pitching Machine Mean ± SD	95% Confidence Interval of the Difference		t-test	p	Cohen *d*
			Upper	Lower			
Movement initiation (Leg off) (s)	-0.028±0.132	0.040±0.163	-0.169	0.031	-1.766	0.138	0.046
Leg off – Leg on (s)	0.349±0.128	0.345±0.163	-0.081	0.088	0.107	0.919	0.027
Leg on – Forward swing initiation (s)	0.089±0.019	0.109±0.067	-0.089	0.050	-0.731	0.498	0.406
Forward swing duration (s)	*0.142±0.017	0.154±0.019	-0.020	-0.003	-3.833	0.012	0.666

Significantly different than Pitching Machine ($p < 0.05$)*

DISCUSSION

The aim of the study was to compare the timing of softball swing phases of lesser-skilled players whilst batting against a softball pitcher and a pitching machine. When compared, the time sequence of the swing motion phases between facing a pitcher and facing a pitching machine conditions, a significant difference was found between these two performances, similarly to the research with the same focus in other sports, i.e. baseball, cricket or tennis [3,10,11].

If we look at our results as a group, they are the same as previous studies [3,10,11]. For example in cricket, differences were found in the initiation of the backswing and forward swing. The batters who faced the bowling machine initiated the backswing much later than when the facing the bowler [10]. Carboch et al. [3] results also showed significant differences in movement initiation and the backswing duration between performances of the stroke on the ball served by the ball machine and served by the player showing like our results differences in performance under pitching machine condition. The mean initial movement time was 50 ms longer for the serving player compared to the ball machine. Praveckova et al. [11] found similar results, where in the case of batting against the pitching machine, participants had a longer phase of upper body load (backswing) on an average of 0.033 s than against the pitcher. Reasons for this included when batting against a pitcher, the motion is more representative, due to more realistic performance stimulus, in timing than against the pitching machine where the swinging phase is longer due to advance cues not being available. This supports Pinder et al. [5] who says that altering the informational constraints of practice caused major changes to the information-movement couplings of developing cricketers.

We observed that performance of every participant was affected in a different component sector of their swing. Basically, we can see that individual results from Table 1 do not really correspond to the overall group results in Table 2, suggesting that evaluating the participants as a group (like previous studies did) can reach inaccurate results and lead to misinterpretations regarding which parts of the swing were affected by visual constraints, which supports our hypothesis. To demonstrate this, our group analysis results show that the forward swing phase significantly differs and the other observed variables reached similar values without any significance. However individual results revealed that only one participant was significantly affected in the forward swing phase and not the others. Participants also showed significant differences in movement initiations and in the duration of leg on – forward swing phase. This can be attributed to the absence of critical information sources such as advance cues of the pitcher, which can affect motor behaviour and movement coordination.

Interestingly, in the case of pitcher, some participants initiated their moves before the ball release, but in the pitching machine condition, after the ball release. The explanation can be found in a similar study on cricket [10]; they suggest that practising batting against bowlers will afford attunement to information from the bowlers' actions and will support the acquisition of appropriate information-couplings for batting in competitive performance; however, batting against bowling machines will result in attunement to early ball flight information, leading to information-movement couplings that may be consistent, but lacks the adaptability needed against bowlers. Conversely, Carboch et al. [3] reported that tennis players initiated their movements earlier in the case of the ball machine. However, this finding may be due to low ball velocity and more time (around 1 s) provided to the participants to intercept the ball. Highly skilled batters and experts are capable utilizing information before the ball release, they initiate their movements before the ball is released, but novice players usually after the ball release [11,23,24]. This may be a skill that needs to be developed, but this is not possible in pitching machine conditions due to the absence of the information sources and the athlete’s action is based purely on his reaction [25-27]. This skill, when players use the pre-release cues and initiate their movement earlier can provide them more time for other parts of their swing in this very quick action, however novice players usually focus on different cues than experts [28-30].

Pinder et al. [5] found that use of pitching machines leads to the removal of critical information sources, which may result in a negative transfer of learning in specific development periods. This causes unintended changes in the coordination of movement, so it is first necessary to master the practical tasks that include some of the specific variables that are available in the competition (batting against the pitcher), so that the players become accustomed to the specific variables available to support the performance. This information, from the movement of the opponent, is obviously absolutely crucial and takes on the importance of experience. Kato and Fukuda [31] found, that expert baseball players use a systematic visual search strategy, utilizing peripheral vision properties to evaluate visually the pitcher's motion efficiently and anticipate the ball's trajectory. Different visual strategies used by novice athletes were shown to affect reaction time of the novice athletes but not the experts [28,32]. Therefore the ecological approach [10] in skill acquisition seems to be very important in all levels. However, visual occlusion training, information processing approach, can also improve anticipation [33]. The players need to learn a proper visual search strategy and use selective attention to spatial cues for their proper interceptive action (spatial cues can provide rich sources of information to assist decision-making and perception-action coupling process). Changes in movement coordination can affect the batting skill; the players could still be able to hit the ball but not effectively or with less power [13]. However, using the pitching machine in a practice session can help to avoid injuries and not overload the pitchers or can help the batters in spatial-temporal orientation - when and where to hit the ball [34].

Renshaw et al. [10] also discovered differences initiation of a cricket batters’ movement. They initiated their backswing earlier when batting against a pitching (bowling) machine compared to the bowler. It is apparent that tennis players use visual information primarily from the trunk, head and racket speed, together with other kinematics during the service action before the racket-ball contact [26,35], allowing for later initiation of movement in comparison to playing against a ball machine. Ball projection machines change not only the information variables that are available up until the ball is released, but also change the natural flight of the ball after its release and using ball machines can affect movement coordination [5].

When turning to analysis of results at a group level, we found several similarities to the conclusions drawn in the previously mentioned studies [2,3,10,11,21,22]. Overall group level results showed a statistically significant difference in the phase of forward swing duration. The rest of the variables are not different with equal or minimal mean difference. However, the individual level results and the specific phases comparison of each batter revealed greater differences in the timing of the swing, which suggest the importance of the individual level analysis. It is not clear why various swing phases were affected among the participants, but one of the explanations could be that participants were lesser-skilled semi-experienced players and not experts. We would endorse the recommendations of Carboch et al. [8] to not to use pitching machines in training sessions too often. When it is used, the player should face the pitcher afterwards to attune to specific visual information sources provided by the pitcher’s kinematics. In the case of softball batting, there is a pitcher´s delivery action movements, point of ball release by pitcher, rotation of the ball imparting spin, and other factors that the batter uses to improve batting performance. In order to ensure the same ball velocity between the pitcher and the pitching machine, the participants faced the pitcher first and afterwards the pitching machine. To control this, counter-balancing [10,15] did not happen in our study (adding pitching machine condition followed by pitcher condition), however controlling this effect would be beneficial. In our study, the participants had 3 practice trials before each condition, so they were able to adjust. Therefore, we would expect the same results if the counter-balancing happened. The results of the study are based on a small sample size. We encourage future studies in this field to analyse results at the individual difference level as opposed to an overall group analysis, when removing visual information in motor behaviour of humans, because their motor responses to reach the goal (ball interception) may be reached through different coordination patterns [15].

CONCLUSION

Using a pitching machine in practice sessions can affect movement coordination. However the pitching machine can't be completely removed from the practice due to some advantages already mentioned above. Based on our results, visual constraints seems to affect the players individually, in particular, the swing timing of various swing phases including the movement initiation. We suggest using individual level analyses next to group level analyses in these type of studies. Even for the more highly-skilled players, advance cues remain important for swing timing in softball. Therefore coaches should be aware of the pitching machine issues, ensuring the pitching machine is used wisely, and in combination with batting against 'live' pitchers in batting training.

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