



# OXYGEN UPTAKE AND HEART RATE RESPONSE DURING BASEBALL PITCHING

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## Introduction

Baseball pitching is considered a high intensity, short duration task repeated numerous times during a game (2). Individualized training specificity for pitchers is a priority for a well-designed conditioning program targeting a wide range of fitness intensities. Heart rate (HR) is the most common parameter to determine target exercise training intensity (3) and the percent of HR maximum (%HRmax) is widely used in baseball training (1, 4). Oxygen uptake ( $VO_2$ ) is another commonly used method to describe exercise intensity and  $VO_{2max}$  is generally accepted as the gold standard criterion measure of cardiorespiratory fitness. However, the accuracy of target training HR depends on the time course of the HR performance curve, which may cause the different calculations of %HRmax that can lead to inaccuracy of target training load (3). Furthermore, exercise prescription based on fixed percentages of  $VO_{2max}$  will lead to an overestimation of target training intensity (6). In this context, %HRmax or  $VO_2$  alone cannot provide an accurate measurement for target training intensity. Therefore, the purpose of this study was to determine exercise intensity of baseball pitching during a 2-inning bullpen session compared to  $VO_{2max}$ , estimated  $VO_{2max}$  (Est.  $VO_{2max}$ ), and HRmax.

## Methods

Fourteen Division I college baseball pitchers (age =  $21.21 \pm 1.66$  years, height =  $184.49 \pm 6.35$  cm, body mass =  $89.10 \pm 9.84$  kg, percent body fat =  $13.37 \pm 4.25\%$ , BMI =  $26.22 \pm 2.66$  kg·m<sup>-2</sup>) volunteered to participate in this study. Each pitcher completed a 1.5-mile run to estimate  $VO_{2max}$  (Figure 1), a treadmill  $VO_{2max}$  test (Figure 2), and a 2-inning bullpen (pitching session) in a lab setting during the offseason (Figure 3).

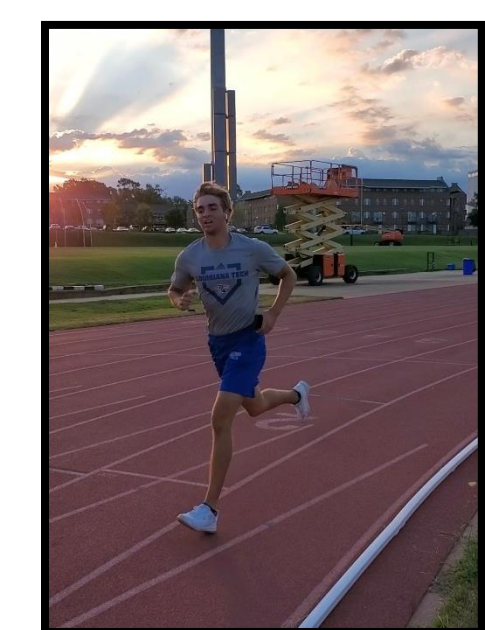


Figure 1. 1.5 mile run.



Figure 2. Treadmill  $VO_{2max}$  test.

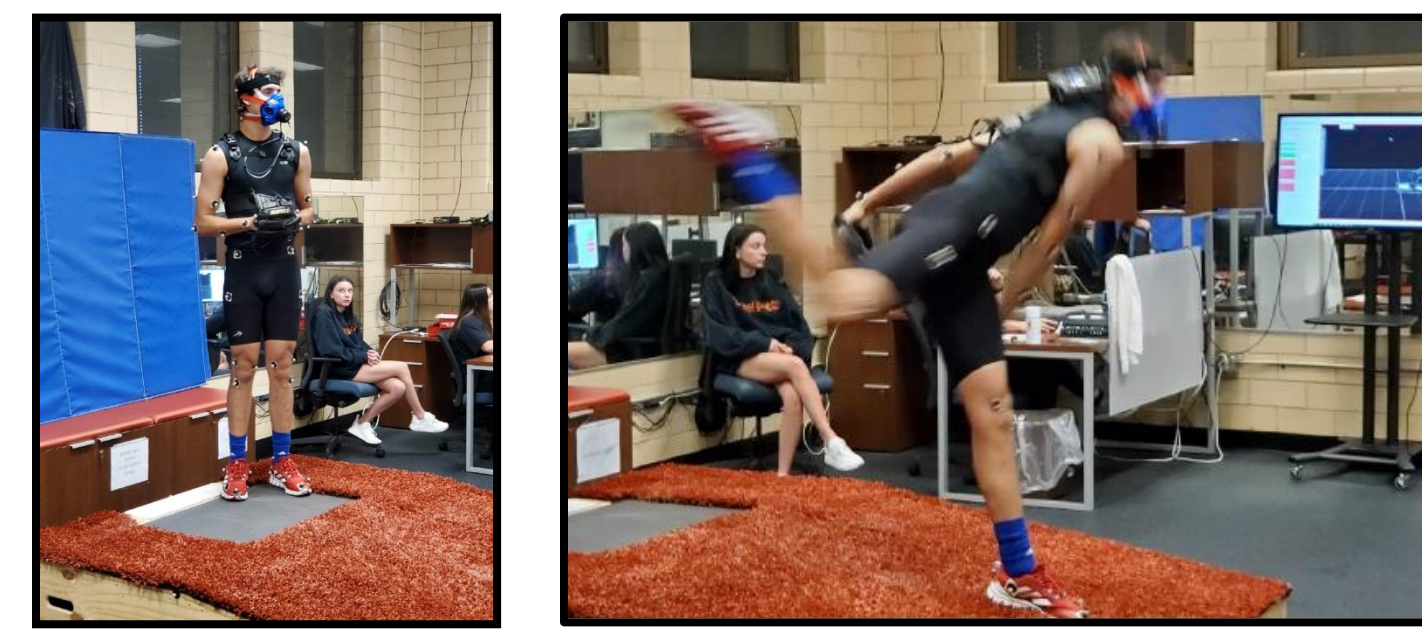


Figure 3. Baseball pitching with  $VO_2$  measurement.

Before the 2-inning bullpen session, each pitcher completed a 30-minute warm-up and standardized throwing program. Then pitchers wore a portable gas analyzer (CosMed K5) and Polar HR monitor to record  $VO_2$  and HR values during the whole session. After 10 minutes rest, each pitcher completed the same testing procedure, which included 7 warm-up throws from a pitching mound, followed by throwing a standardized 16-pitch routine which represented the 1<sup>st</sup> inning (6 min). Then pitchers sat down and rested for 6 minutes, which represented being in the dugout during the team's offensive half inning. Then pitchers began the 2<sup>nd</sup> inning of pitching using the same sequence of events as the 1<sup>st</sup> inning. Once the 2<sup>nd</sup> inning was completed, pitchers sat down and rested for 6 minutes. The testing procedure is displayed in Figure 4. All  $VO_2$  data were normalized to each pitcher's  $VO_{2max}$  (% $VO_{2max}$ ) and estimated  $VO_{2max}$  (% estimate  $VO_{2max}$ ). Heart rate data was normalized to each pitcher's % HRmax. To compare the intensity between the two innings, paired sample *t*-tests were run. An alpha level of  $p \leq 0.05$  indicated significance.

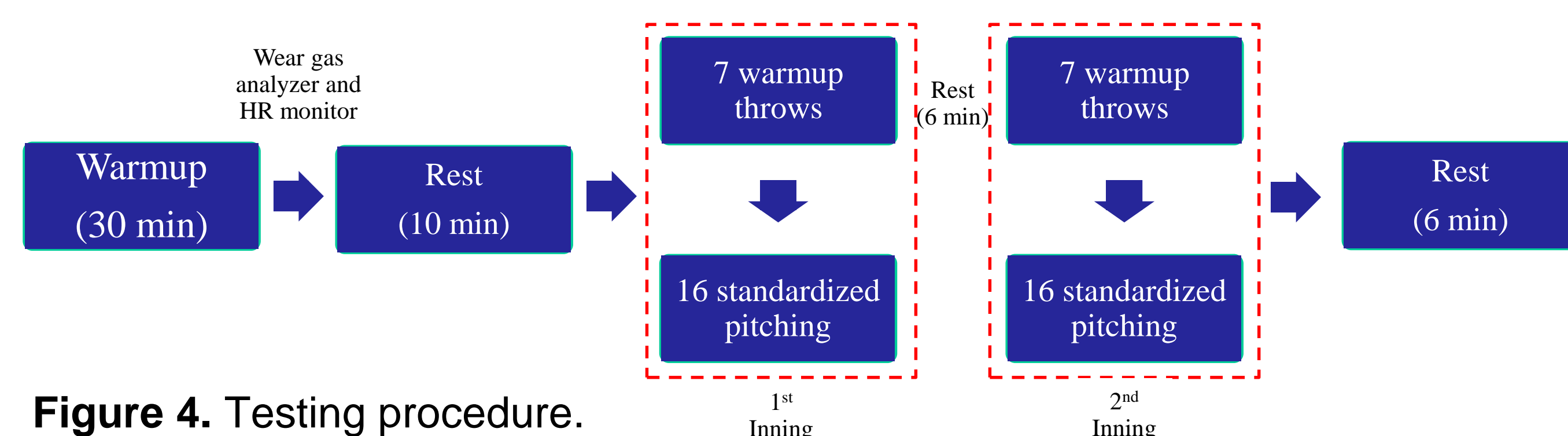


Figure 4. Testing procedure.

## Results

Table 1. Participants' descriptive characteristics,  $VO_{2max}$ , and Estimated  $VO_{2max}$  (Mean  $\pm$  SD).

	Age (years)	Height (cm)	Weight (kg)	Body fat (%)	$VO_{2max}$ (mL/kg/min)	Est. $VO_{2max}$ (mL/kg/min)
Mean	21.21	184.49	89.1	13.37	46.41	45.74
SD	1.66	6.35	9.84	4.25	3.56	3.58

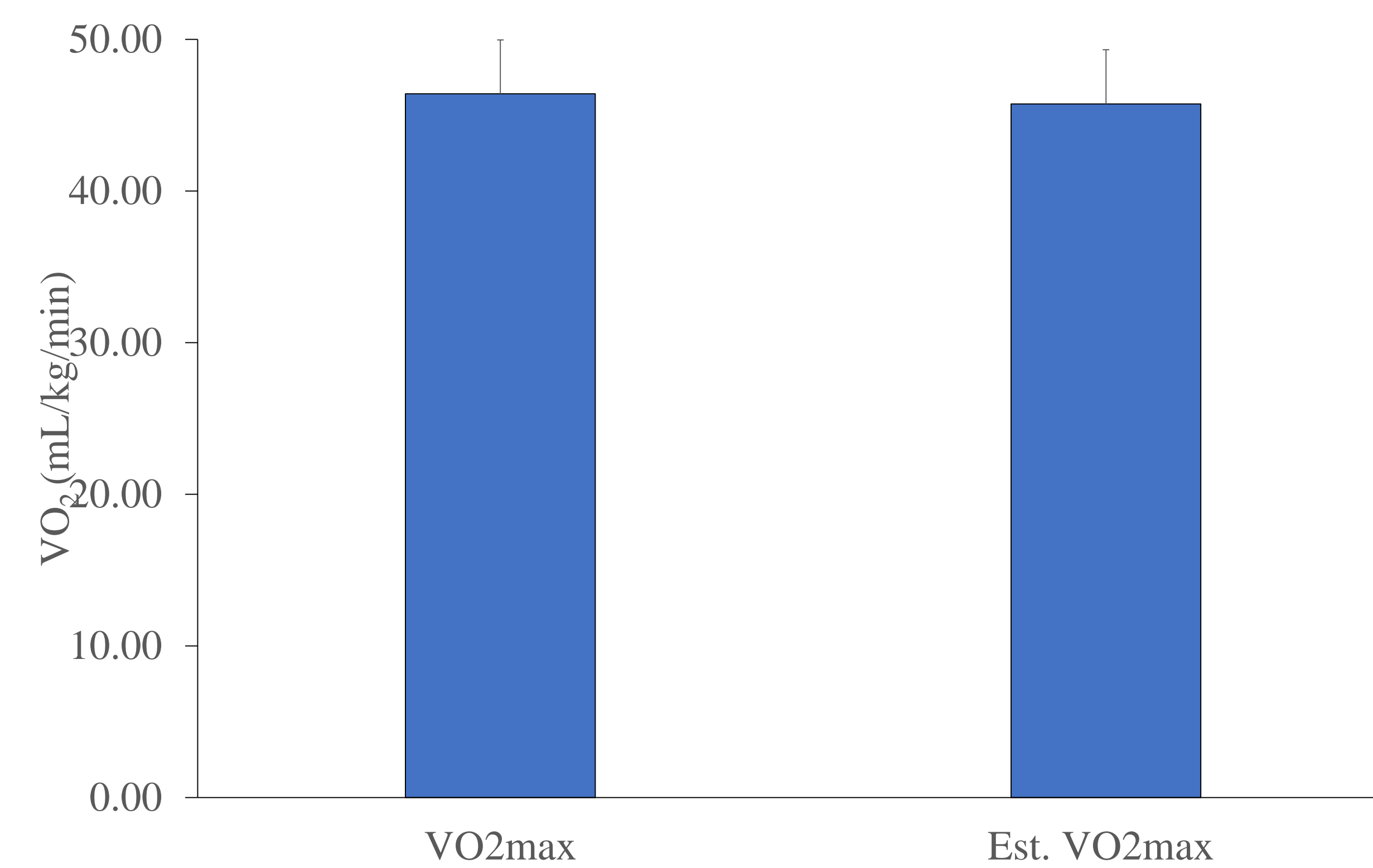


Figure 5. Pitcher's  $VO_{2max}$  and Estimate  $VO_{2max}$  (Mean  $\pm$  SD).

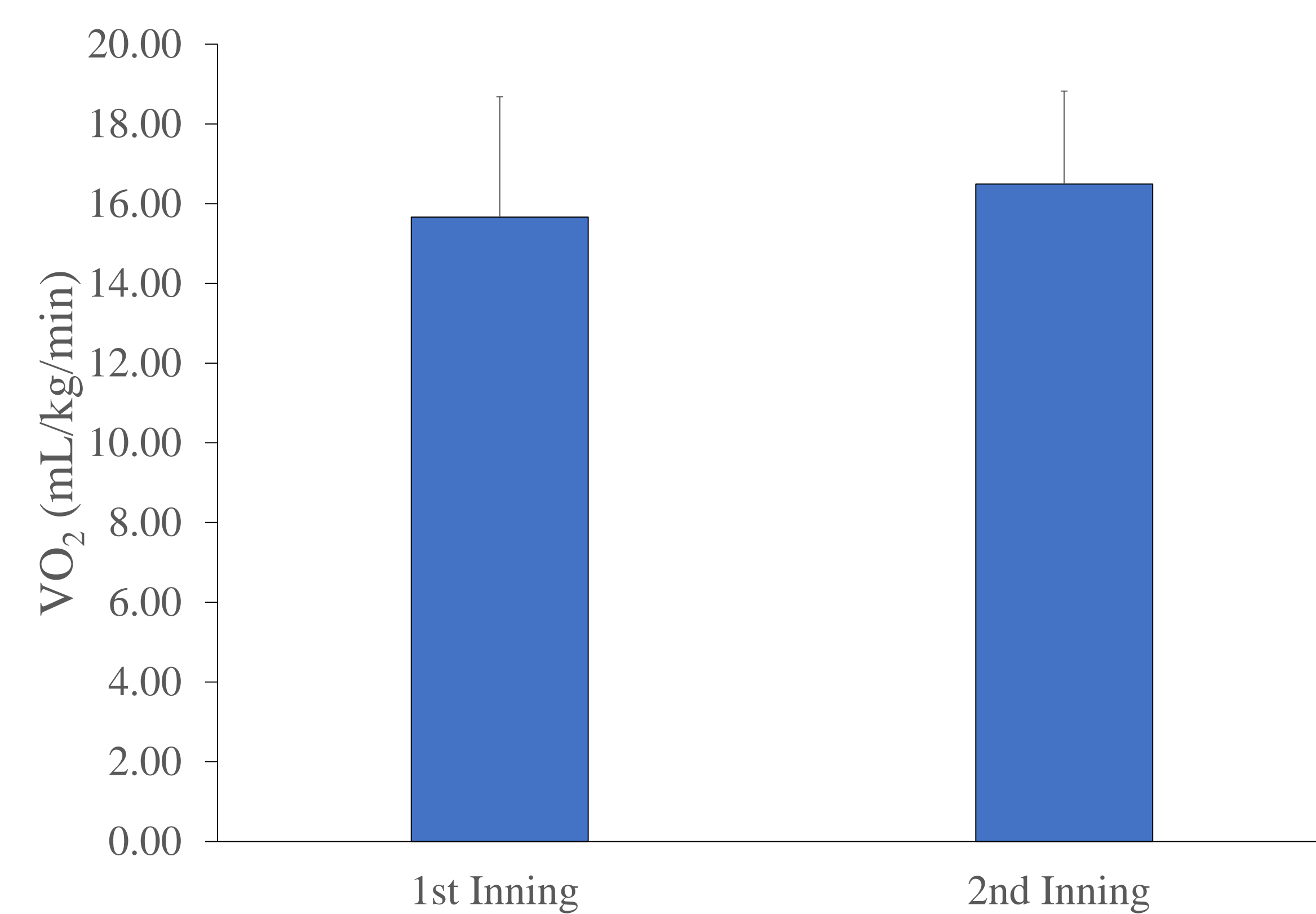


Figure 6. Pitcher's oxygen uptake ( $VO_2$ ) during 1<sup>st</sup> and 2<sup>nd</sup> innings (Mean  $\pm$  SD).

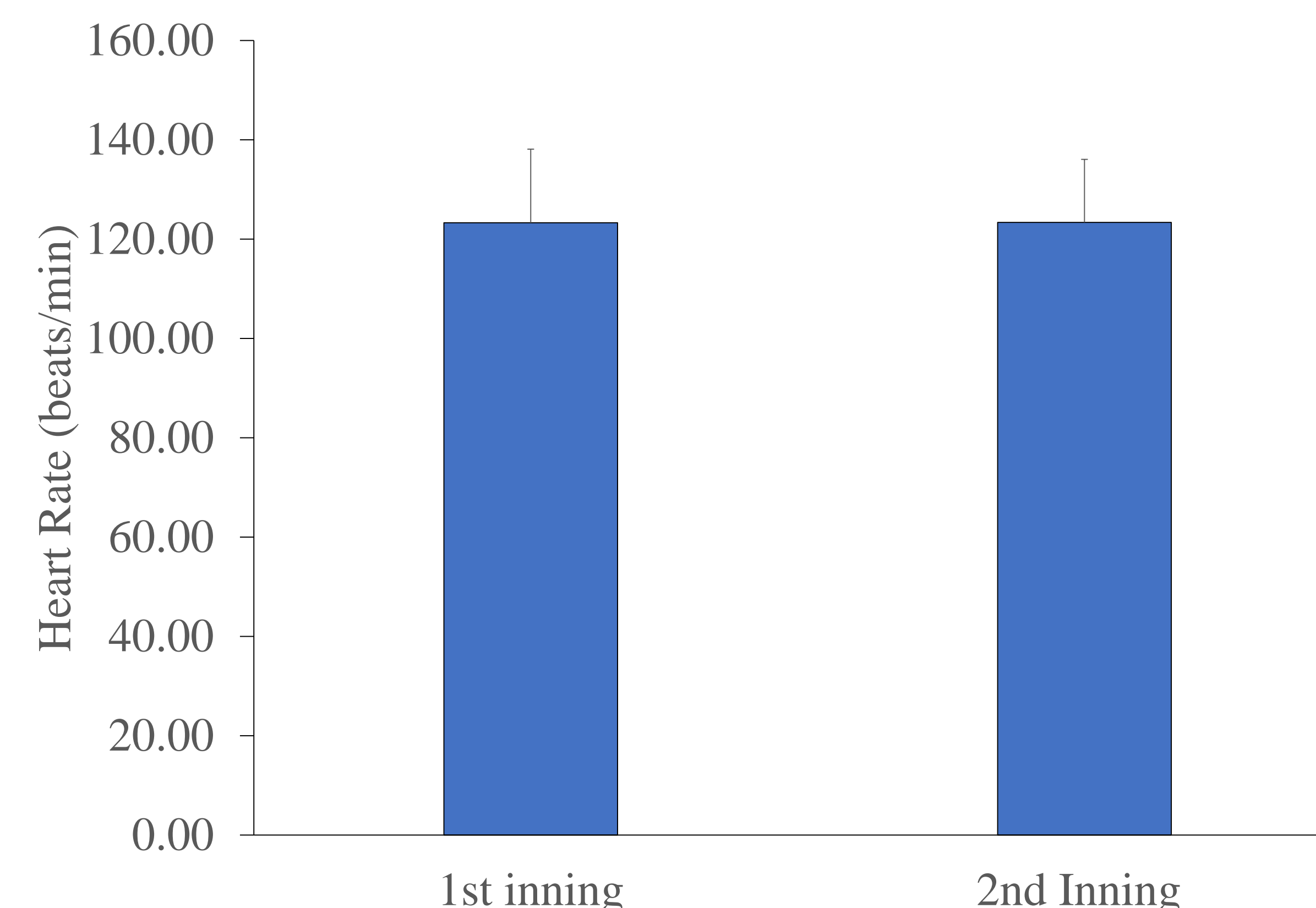


Figure 7. Pitcher's heart rate during 1<sup>st</sup> and 2<sup>nd</sup> innings (Mean  $\pm$  SD).

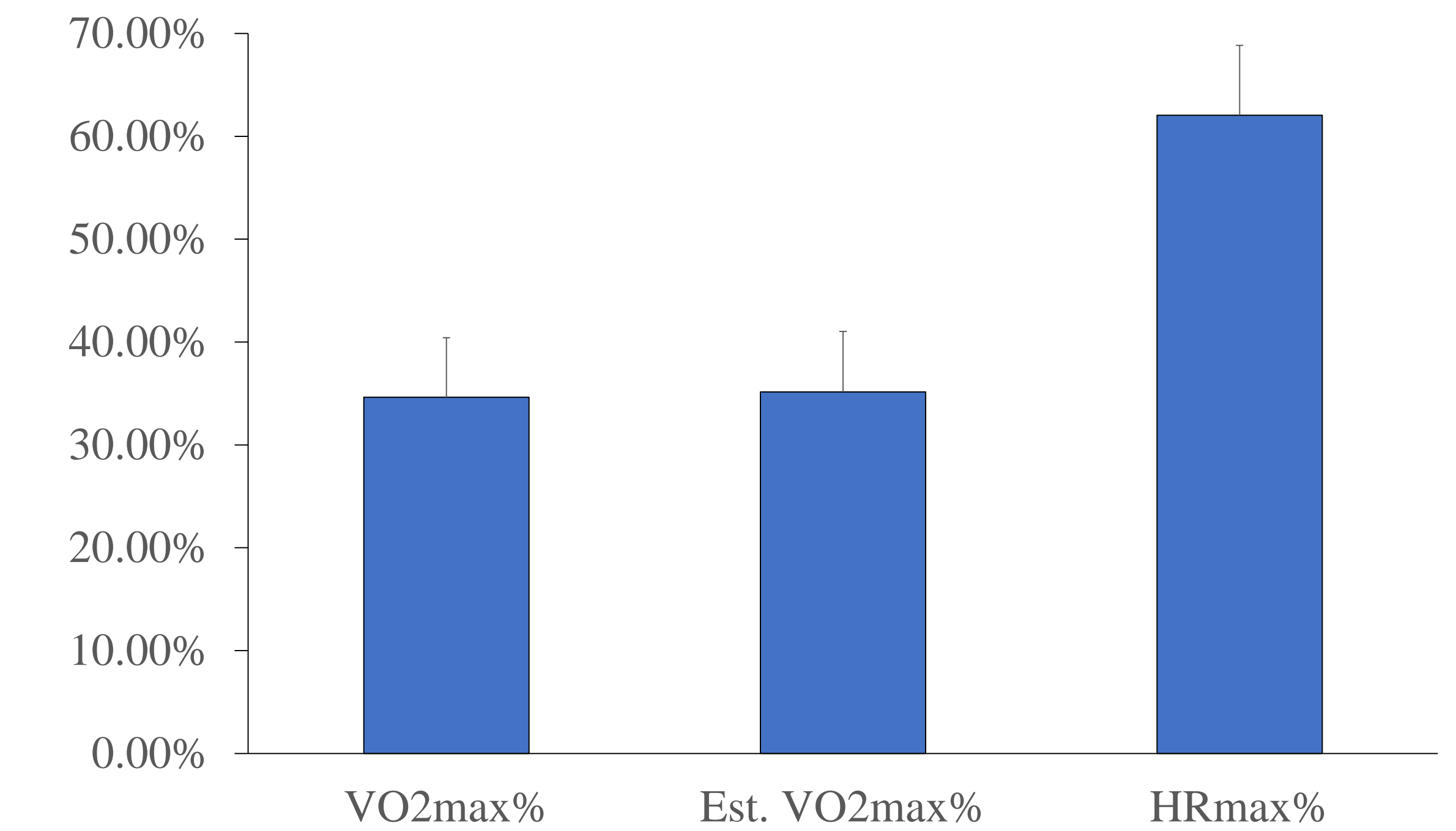


Figure 8. Exercise intensity in two innings calculated as percentage of  $VO_{2max}$ , Est.  $VO_{2max}$ , and HRmax (Mean  $\pm$  SD).

## Conclusions

The group mean  $VO_{2max}$  and estimated mean  $VO_{2max}$  were  $46.41 \pm 3.56$  and  $45.74 \pm 3.58$  mL·kg<sup>-1</sup>·min<sup>-1</sup> (Figure 5), similar to previous research (2, 4). There was no significant difference between the two tests ( $p = 0.46$ ). There were no significant differences in intensity between the two innings for  $VO_2$  and HR ( $p = 0.28$  and  $p = 1.0$ ). Mean  $VO_2$  during simulated pitching was similar to previous research (4); however, mean HR during 2 innings of pitching was slightly lower (123.4 bpm) than two previous studies (135.0 and 133.5 bpm) (4, 5). The group mean inning intensity was 34.64% (range of 24% to 45.36%) of  $VO_{2max}$ , 35.15% (range of 24.36% to 46.02%) of estimated  $VO_{2max}$  similar to previous research (4), and 62.05% (range of 49.95% to 75.56%) of HRmax, respectively (Figure 8). Previous research (1) that collected HR values during actual competitive professional games reported mean %HRmax of 84.8%, stating that in-game values may be higher because it could be influenced by psychological demands associated with actual in-game competition.

These data suggest that the overall cardiorespiratory fitness intensity of baseball pitching during a bullpen session was "light" when using percentage of  $VO_{2max}$  or estimated  $VO_{2max}$  as the criterion, and "light to moderate" when using percentage of HRmax as the criterion. This is similar to previous research (4, 5).

## Practical Applications

Maximal cardiorespiratory fitness values can be used to design baseball pitchers' conditioning program to create "very light to near maximal" intensity days that are individualized and respective to each pitcher's conditioning level. This recommendation is supported by previous research (1, 4, 5). Estimated  $VO_{2max}$  from a 1.5-mile run can be used as a reliable test to assess cardiorespiratory fitness levels when gas analysis is not available.

## References

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