Table 1. Summary of Clinical Findings for Both Cases

						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
IPD	Female Nonathletes	227	61.54	2.66	0.18	61.19	61.88	54.00	66.32
	Male Nonathletes	189	64.32	1.50	0.11	64.11	64.54	59.03	68.74
	MLB Players	149	69.91	2.38	0.20	69.52	70.29	66.10	74.97
	Total	565	64.68	4.04	0.17	64.34	65.01	54.00	74.97
PD	Female Nonathletes	29	3.58	0.27	0.05	3.47	3.68	2.91	4.03
	Male Nonathletes	33	3.57	0.31	0.05	3.46	3.68	3.05	4.12
	MLB Players	195	3.09	0.29	0.02	3.05	3.13	2.08	3.68
	Total	257	3.20	0.36	0.02	3.16	3.25	2.08	4.12

Table 2. ANOVA Tables for IPD and PD

		Sum of Squares	df	Mean Square	F	Sig.
IPD	Between Groups	6337.22	2	3168.61	621.50	0.001
	Within Groups	2865.26	562	5.10		
	Total	9202.48	564			
PD	Between Groups	11.09	2	5.54	64.81	0.001
	Within Groups	21.73	254	0.09		
	Total	32.81	256			

and blinds covering the windows in order to obtain the same luminance level (344cd/m^2).

Test protocol: To ensure accuracy of IPD and PD, it is important that three conditions are met: a) the distance from the screen is 60cm, b) the eyes remain stationary during the last 700 milliseconds, and c) the participant looks at the stimulus. To assist with these conditions, a chin rest is recommended for younger patients or for those with certain movement-related disorders. Additionally, error handling is employed, using the eye tracker to determine the location of the participant's eyes on the screen, ensuring that he/she is looking at the target during the last 700 milliseconds when IPD and PD are being calculated. Error proofing is also included for distance from the screen, where the participant will be forced to retest if they move outside the required 60cm during the testing time. If this occurs, an error message will let the tester know, and the test will be redone. This further enhances the confidence that the participant was confirmed as "on the stimulus" when the calculations were made.

Furthermore, to ensure overall testing accuracy, the two examiners were trained on how to run each test with accuracy and consistency and were given one hour of dedicated training. This concluded with a test in the form of a demonstration to an experienced tester, requiring a "passing" grade prior to testing any participants.

Data Analysis

Two sets of analyses were conducted. Preliminary analyses examined skewness and kurtosis for IPD and PD and provided descriptive statistics for the two variables, including means, standard deviations, standard errors, confidence intervals, minimum values, and maximum values. Main analyses examined group differences in IPD and PD. Specifically, one-way ANOVAs analyzed differences in IPD and PD between female non-athletes, male non-athletes, and MLB players. The assumption of homogeneity of variances across groups was tested using the Levene test. If assumptions were violated, Kruskal-Wallis tests analyzed

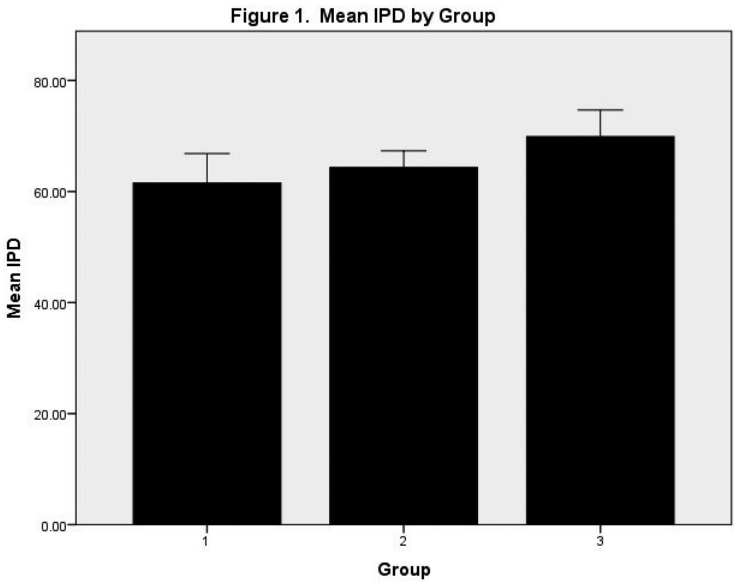

Figure 4. *Mean IPD per group. Group 1 Female, Group 2 Male, Group 3 athlete.*

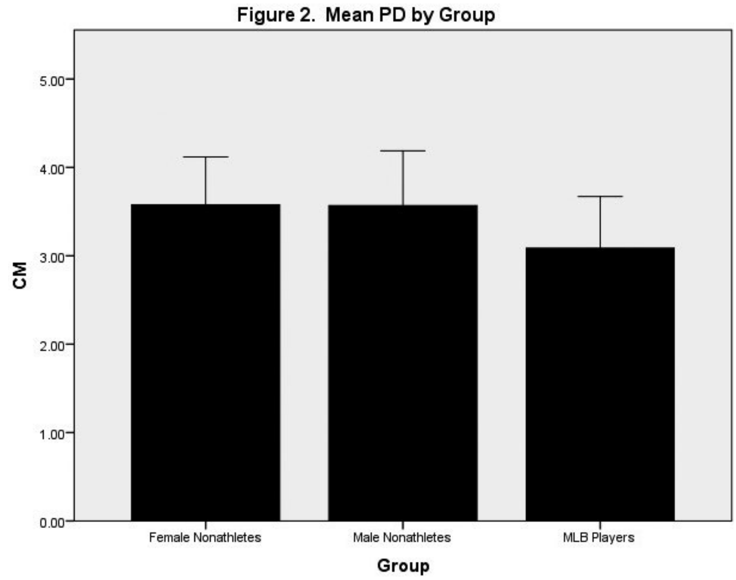

Figure 5. *Mean PD per group. Group 1 Female, Group 2 Male, Group 3 athlete.*

Table 3. Post Hoc Tests IPD and PD.* The mean difference is significant at the 0.05 level.

							95% Confidence Interval	
Dependent Variable				**Mean Difference (I-J)**	**Std Error**	**Sig**	**Lower Bound**	**Upper Bound**
IPD	**Tukey HSD**	Male Nonathletes	Male Nonathletes	-2.79*	0.22	0.0005	-3.31	-2.26
			MLB Players	-8.37*	0.24	0.0005	-8.93	-7.81
		Female Nonathletes	Female Nonathletes	2.79*	0.22	0.0005	2.26	3.31
			MLB Players	-5.58*	0.25	0.0005	-6.16	-5.00
		MLB Players	Female Nonathletes	8.37*	0.24	0.0005	7.81	8.93
			Male Nonathletes	5.58*	0.25	0.0005	5.00	6.16
	Dunnett T3	Male Nonathletes	Male Nonathletes	-2.79*	0.21	0.0005	-3.28	-2.29
			MLB Players	-8.37*	0.26	0.0005	-9.00	-7.74
		Female Nonathletes	Female Nonathletes	2.79*	0.21	0.0005	2.29	3.28
			MLB Players	-5.58*	0.22	0.0005	-6.12	-5.05
		MLB Players	Female Nonathletes	8.37*	0.26	0.0005	7.74	9.00
			Male Nonathletes	5.58*	0.22	0.0005	5.05	6.12
PD	**Tukey HSD**	Male Nonathletes	Male Nonathletes	0.01	0.07	0.9937	-0.17	0.18
			MLB Players	.49*	0.06	0.0005	0.35	0.63
		Female Nonathletes	Female Nonathletes	-0.01	0.07	0.9937	-0.18	0.17
			MLB Players	.48*	0.06	0.0005	0.35	0.61
		MLB Players	Female Nonathletes	-.49*	0.06	0.0005	-0.63	-0.35
			Male Nonathletes	-.48*	0.06	0.0005	-0.61	-0.35
	Dunnett T3	Male Nonathletes	Male Nonathletes	0.01	0.07	0.9994	-0.17	0.19
			MLB Players	.49*	0.05	0.0005	0.35	0.63
		Female Nonathletes	Female Nonathletes	-0.01	0.07	0.9994	-0.19	0.17
			MLB Players	.48*	0.06	0.0005	0.34	0.63
		MLB Players	Female Nonathletes	-.49*	0.05	0.0005	-0.63	-0.35
			Male Nonathletes	-.48*	0.06	0.0005	-0.63	-0.34

group differences. Significant between-group differences were followed up with Tukey and Dunnett (T3) post-hoc tests. Alpha was set at $p<0.05$ for all analyses.

Results

Both IPD and PD appeared to be normally distributed. That is, skewness and kurtosis were less than +/- 1 for both variables. Table 1 presents descriptive statistics for IPD and PD, including means, standard deviations, confidence intervals, minimum values, and maximum values.

One-way ANOVAs examined differences in IPD and PD across groups. Table 2 presents F statistics and p-values for these tests.

For IPD, there was a significant difference ($F(2, 562) = 621.50$, $p < 0.0005$, $\eta 2 = 0.69$) between female non-athletes, male non-athletes, and MLB players. IPD did not meet the assumption of homogeneity of variance ($p<0.0005$). Consequently, the Kruskal-Wallis test was also used to examine differences in IPD by group. There was a significant difference in the IPD distributions between female non-athletes, male non-athletes, and MLB players ($H(2, 565) = 405.77$, $p<0.0005$). Post-hoc tests, provided in Table 3, indicated that for IPD, all three groups were significantly different from one another.

Female non-athletes had the smallest IPD (Figure 4). Male non-athletes had a larger IPD than female non-athletes. MLB players had the largest IPD. That is, the MLB players had a larger IPD than both male and female non-athletes.

For PD, there was a significant difference ($F(2, 254) = 64.81$, $p < 0.0005$, $\eta 2 = 0.34$) between female non-athletes, male non-athletes, and MLB players (Figure 5).

ID met the assumption of homogeneity of variance ($p=0.65$). Post-hoc tests, provided in Table 3, indicated that for PD, male and female non-athletes were not significantly different from one another. MLB players were, however, significantly different from both male and female non-athletes. Both male and female non-athletes had a larger PD than MLB players.

Discussion

The aim of this study was to determine whether a difference existed in IPD between professional baseball players and the non-athlete population. To determine that differences were not due to the reliability or validity of the test or test-taking procedure, the same process that was used in past research by Murray, Hunfalvay, and Bolte (in press)[10] was employed here. Using this process resulted in high test reliability and accuracy, therefore providing confidence that the results were not due to a lack of test consistency or accuracy.

The results from this study indicate that significant differences in IPD exist between women, men, and MLB athletes. Females had the smallest IPD ($M = 61.54$, $SD = 2.66$), male non-athletes' IPDs were larger than females' but smaller than MLB athletes' ($M = 64.32$, $SD = 1.50$), and MLB athletes had the largest IPDs ($M = 69.91$, $SD = 2.38$). These findings are consistent with past research in IPD, where non-athlete males and females were found to have differences in mean IPD.[11,12]

Significant differences in IPD were found between non-athletes (males and females) and the MLB (athlete) group. IPD influences many vision components that are important in sport, specifically in baseball, including the amount of stereo separation of two images that are combined in the brain to produce stereo perception.[11,15] Stereo perception is important in the rapid 3-dimensional processing involved in catching a ball, for instance. A wider IPD has a greater angle of disparity, resulting in greater stereo acuity.[18,25-27] It has been identified that athletes have greater stereo acuity than non-athletes. After reviewing results from this study, one possible explanation may be IPD. These findings may lead to future research investigating whether young athletes who have a wider IPD experience more success in sport due to enhanced stereo acuity. IPD is not fully developed until 19 years old in males and 14 years old in females;[28] therefore, it is important that those involved in working with athletes (ophthalmologists, optometrists, coaches, and parents) be aware that this may affect performance. The results of this study also suggest that for adult professional baseball players, IPD may be one factor in elite-level performance.

Past research was inconsistent in determining non-athlete gender differences in PD. The results of this study found that male and female non-athletes were not significantly different from one another in post-hoc testing. These results are consistent with Hashemian et al.,[14] who found no significant difference in PD between gender. Interestingly however, this study also found significant differences between non-athletes and MLB pupil size. A smaller PD size has been shown to improve image quality, as it limits diffraction[7] as well as depth of focus.[9] Both image quality and depth of focus are very important attributes when playing baseball. Past research has shown that expert baseball players often look for the pitcher's rotation at the elbow and hand placement[28] and look to track the ball visually, including the rotation of the ball detected by looking at the seams, when batting.[29] Placement of the hand on and rotation of the ball at 60 feet 6 inches away may be affected by image quality. The ability to track a ball at 95 miles per hour with rapid changes in depth is clearly related to depth of focus. The results of this study suggest that a significantly smaller PD for MLB players compared to non-athletes may be a factor in their success.

Future studies should consider ethnicity as a variable in examining IPD and PD in athletes and non-athletes. Not making a link between IPD, PD, and performance statistics within the baseball group is a limitation of this study. Future studies should examine whether those within the MLB group differ from one another on IPD and PD and whether those differences are statistically relevant when compared with performance outcomes such as on-base percentage and batting average, for example.

Taken together, MLB athletes showed significantly wider IPD and significantly smaller PD compared to non-athletes (males and females). Past research has shown that these biological structures affect important visual skills needed for playing baseball. Baseball performance depends on a multitude of skills, techniques, and abilities, some learnt and some innate. Obviously, IPD and PD, along with athletes' visual skills, are only part of overall performance. However, when the blink of an eye can affect the ability to see a ball,[30] seemingly small differences in biological make-up like IPD and PD may provide another component in a long equation that determines success.

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