EFFECT OF WEARING SINGLE-VISION & PROGRESSIVE LENSES ON EYE & HEAD MOVEMENTS DURING THE GOLF PUTTING STROKE

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Abstract

This study investigated the effects of different progressive lenses and a single-vision lens on eye, head, and putter motions during the golf putting stroke in presbyopes. Six subjects ranging in age from 49 to 69 years, with golf experience ranging from modest to high, participated in the study. Three lens conditions were tested: single-vision distance lenses (SV), newer "soft" design (PAL1), and older "hard" design (PAL2) progressive lenses. The two progressive lenses have different intermediate zone widths. For each condition, the subject completed 15 putts to a standard size golf-hole target 9 feet away. Eye, head, and putter movements were recorded. The data were analyzed over the interval from the beginning of the putting stroke to the moment of ball impact. The root mean square (RMS) of the eye, head, and putter movements within this time interval were calculated for each record, and the data were averaged across subjects. Putting accuracy was also monitored. The results showed that the mean RMS values of the eye movements were not significantly different among the three conditions, although it was slightly smaller for the PAL2 condition. The mean head movement RMS values were not significantly different between the SV and PAL1 conditions, whereas it was significantly higher for the PAL2 than the PAL1 condition. In addition, putt amplitude, duration, and accuracy were not significantly different among the three conditions. There were no obvious differences between experienced and inexperienced golfers. For the PAL2 condition, the larger head movements observed (and the corresponding smaller eye movement variation) may be due to its smaller intermediate zone width. Progressive addition lens users have been previously observed to remain well within the boundaries of the intermediate zone of clarity, possibly by adopting a conservative eye movement strategy, and therefore are forced to compensate with larger head movements. The results provide new and useful guidelines for the future design of progressive lenses to improve their performance during outdoor activities such as golf.

Key Words

eye movements, golf putting movements, head movements, presbyopia, progressive addition lenses, putting accuracy, single vision lenses, wireless sensor system

INTRODUCTION

Sports science and sports medicine are becoming a popular means of addressing specific questions posed by athletes and their trainers concerning the body's forces and actions during athletic motions. It has, for example, provided valuable information about the golf swing and physical forces impacting on the golf ball.[1,2] Much of this information has been obtained using high-speed photography and video systems spanning almost a century.[3-7] Indeed, the components of the golf swing have been studied in great detail over the past 50 years. However, there is a surprising lack of objective simultaneous measurements of eye and head motion during the golf swing, especially for putting.[8]

Putting is a crucial element in golf.[9-11] This is demonstrated by statistics compiled by the Professional Golfers Association, which showed that the best players in the world expend approximately 40% of their total strokes in a round on putting.[12] Professional golf instructors and sports psychologists have stressed the importance of minimal or no eye and head movements throughout the putting stroke. The eyes are important because they provide accurate perception of the distance and direction to the target hole location to result in successful execution of a putting stroke. If the eyes are fixated elsewhere at a position other than the ball, this can lead to an improper stroke and a missed putt. Head position is also important because it allows for maintenance of a stable visual environment. Head movement during the stroke can lead to misalignment and a missed putt.

With the increased number of baby boomers playing golf, progressive addition lenses (PALs) have become an important component of golf activities. As one ages, the accommodative response decreases, and beyond the age of about 50 years, the crystalline lens acts essentially as a fixed-focus optical system.[13,14] The PAL can remedy this by providing a means to see clearly as a continuum at far, intermediate, and near distances. Thus, during a round of golf, the PAL allows the player to see the ball at address, midflight, and at a far distance where the ball lands. The need for clear vision through the PAL is particularly important during putting, since viewing through different portions of the PAL can affect target clarity and awareness of surround during the execution of the putting stroke.

Different PAL designs provide different attributes. The older "hard" design lenses have an abrupt and narrow intermediate zone, which may induce more head movements for accurate visualization.[15-17] On the other hand, the newer "soft" design lenses have a less abrupt and wider intermediate zone that provide a larger field of view, thus requiring less eye and head movements for viewing a scene.[15-17] These attributes may have different effects on vision function during physical activities such as golf. This study investigated the differences in eye and head movements of golfers during the putting stroke while wearing single-vision (SV), newer "soft" design (PAL1), and older "hard" design (PAL2) progressive lenses.

METHOD

Apparatus

A wireless sensor system was custom-designed by the first author. It allowed for simultaneous recording of eye, head, and putter motions during the golf putting stroke (Figures 1 and 2). Head movements were measured using an accelerometer placed in a small circuit board, which was mounted on the beak of a visor.[18-20] The eye sensor consisted of infrared emitter-detector pairs that were aimed at the horizontal limbal boundaries of the eye,

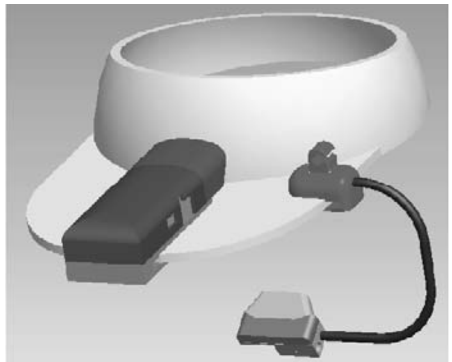

Figure 1. Visor with head sensor (attached to beak of visor) and eye sensor (below the visor).

where the reflectance is directly related to horizontal eye position. A flexible wire and adjustable plastic assembly were anchored on the side of the visor to position the eye sensor at a fixed distance in front of the left eye. This assembly configuration provided for full adjustment of sensor position in different users. In addition, putter motion was measured using an accelerometer placed in a circuit board which was mounted on the shaft of the putter. The two circuit boards on the visor and the putter shaft contain antennas that send the head, eye, and putter signals to a receiving board, which is plugged directly into the USB port of the PC for serial data transmission.

Subjects and Procedure

Four male and two female subjects, ranging in age from 49 to 69 years, participated in the study. Two of the male subjects were experienced in playing golf, whereas the others were novices.

Three lens conditions were used:

1. Single vision CR-39 lens spectacles prescribed according to the subject's distant vision correction.
2. PAL 1, which is a "soft" newer design with a 3.9mm(wide) intermediate zone.
3. PAL 2, which is a "harder" older design with a 2.3mm intermediate zone.

Both PAL designs incorporated the subject's present prescription. The wider intermediate zone (PAL1) lens has less unwanted astigmatism in the periphery, while the narrower intermediate zone (PAL2) lens has more unwanted astigmatism in the periphery. None of the subjects were adapted to any one of the lens styles, nor were they given any specific instruction on how to use the lenses.

Figure 2. Subject wearing spectacle lenses and visor with attached head and eye sensors.

Figure 3. Subject putting while wearing recording system containing eye, head, and putting motion sensors.

The sequence of spectacle lenses tested was randomized among the subjects. For each condition, the subject completed 15 putts to a standard size golf-hole target 9 feet away on a smooth artificial grass environment. Eye, head, and putter movements were recorded over 3-sec intervals at a 64 Hz sampling rate using the wireless sensor system (see Figure 3).

Data Analysis

The data were analyzed using programs written in C++[a] and MATLAB[b] codes. The results were displayed in three channels as position time courses for putter, eye, and head movements. Also displayed were the corresponding velocity traces. For each record, the beginning of the putt (i.e., the take-away), as well as the

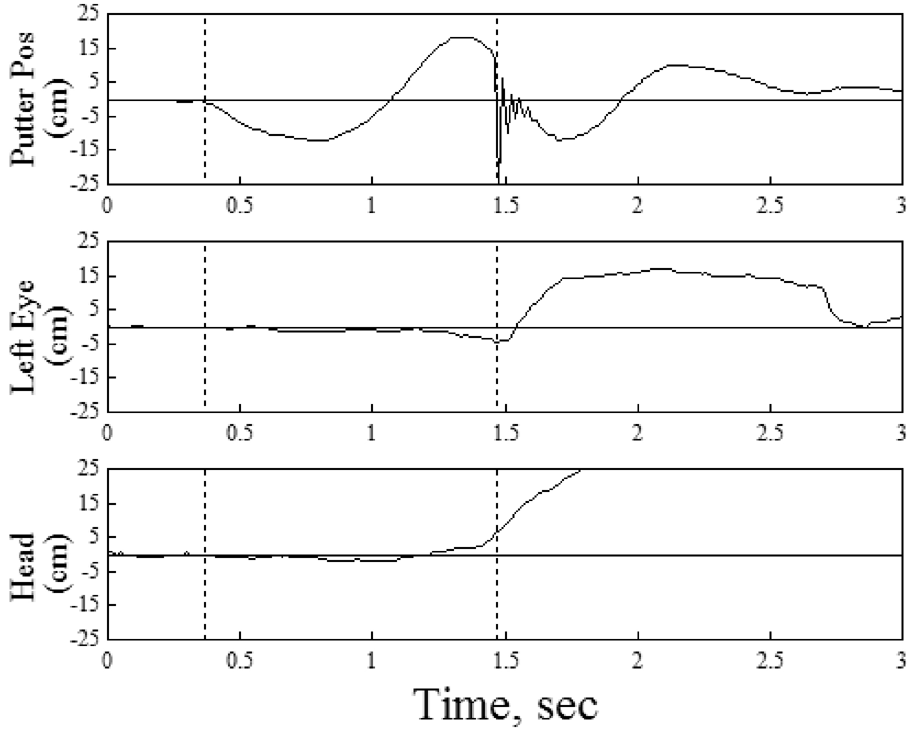

Figure 4a. Record showing relatively small eye and head movements before ball impact at 1.5 sec (vertical dashed lines) with PAL2 lens. Upwards on plot is towards the hole. Putter position is estimated from acceleration data, and is used primarily to determine the point of impact.

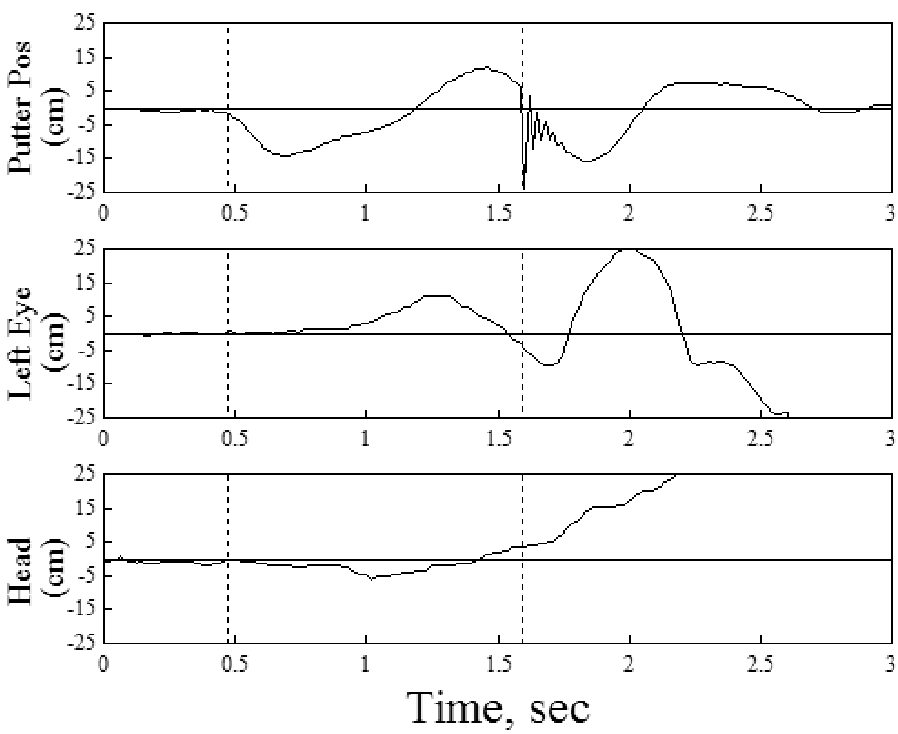

Figure.4b. Record showing relatively large and variable eye and head movements before ball impact at about 1.5 sec (vertical dashed lines) with PAL1 lens.

Table 1. Average Values (n=6)

	SV	PAL1	PAL2
Eye (rms, cm)	6.23	6.77	5.37
Head (rms, cm)	4.70	4.64*	5.95*
Putt amplitude (cm)	34.5	36.3	36.2
Putt Duration (sec)	0.86	0.90	0.90
Putt (% made)	54.0	39.6	42.8

** = p<0.05*

end of the putt (i.e., return to the point of impact), were marked visually on the PC screen. The program calculated the RMS of eye and head movements, as well as the duration and amplitude of the putt, over the marked time interval.

The data from each subject were averaged, and the averaged data for the six subjects were used in the statistical analysis. One-tailed t-tests (MATLAB[b] Statistical Analysis Toolbox) were performed to assess the statistical significance of differences between the progressive and SV add lenses for the various parameters: RMS of eye and head movements, putt amplitude, putt duration, and the percentage of putts made.

RESULTS

Typical records during the putting stroke are shown for small (Figure 4a) and large (Figure 4b) amounts of eye and head movements before ball impact. The data were converted to equivalent linear displacement (in cm) on the putting surface.

The mean RMS values of the eye movements were not significantly different among the three conditions, although it was slightly smaller for the PAL2 condition. The mean head movement RMS values were not significantly different between the SV and PAL1 conditions, whereas they were significantly higher for the PAL2 versus the PAL1 condition (t-test, $p < 0.05$). In addition, putt amplitude, duration, and percentage made were not significantly different among the three conditions (see Table 1). There were no obvious differences between the experienced and inexperienced golfers.

DISCUSSION

Among many other factors, there are two physical factors that may lead to missed putts. Putting on a smooth artificial surface does not necessarily mean a perfectly flat surface. There may be grain and slight contour variations even for an apparently straight putt, similar to actual greens that appear to be flat. Nevertheless, the subjects were given a few trial putts prior to the experiments, and this in part allowed them to compensate for any "break" (i.e., a specific golf term referring to the expected turn of the ball due to the contour or grain) on the artificial surface. Also, the PAL lenses may contribute in part to a misreading of the true position of the target due to the prismatic effect through the periphery of the lens. Thus, to accurately assess alignment of the putt, the subject should look at the golf hole through the central portion of the PAL lens by turning the head fully rather than partially, as is normally done with single vision lenses.

The amount of accommodation needed for the putts was calculated to range from 0.68 to 0.77 D, which corresponds to a range of distances from the eye to the ball from 148 cm to 131 cm. If the subject viewed through the central distance-refraction portion of the PAL lens, and accounting for a depth of focus of about ±0.25 D,[21,22] this would leave about 0.5 D of accommodative stimulus. Thus, there would be a small amount of blur except for the younger presbyopes, who may be able to accommodate for the remaining dioptric stimulus. However, all of these presbyopic subjects should be able to see the ball clearly by a slight upward tilt of the head to look through a particular portion of the progressive add lens that just compensates for the optical power of the target. But this may not be the most comfortable position, so subjects may compromise by reducing the amount of head tilt to achieve a reasonably comfortable posture while permitting a small amount of defocus blur.

The results of the present investigation demonstrated clear but subtle differences in eye and head movements during golf putting with the three lenses. For the PAL2 lens, which has the most restricted clear field-of-view, head movement variation was significantly greater, while eye movement variation was smaller than with the PAL1 lens. Regardless of the type of lens, head and/or eye movements are undesirable during golf putting, as golf-teaching professionals stress in their lessons.[9] Presumably, the presence of such movements would impact adversely on putting accuracy. While putting accuracy was not significantly different for the three lenses, it was about 10% better with the SV versus either PAL lens. Perhaps this finding was not statistically significant due to the relatively small sample size. An expanded study with a larger sample size may determine whether it is indeed statistically significant, and is so, this percentage difference could have important performance and thus lens design consequences.

The present findings are consistent with earlier studies in our laboratory with PAL lenses, but involving various near vision reading tasks.[15-17] In those studies, as the PAL intermediate zone became narrower and restricted the clear field-of-view, both eye and head movement amplitudes increased, as well as the time to attain fixational stability after a saccade. Other dynamic aspects of eye and head movements, such as peak velocity, were not affected and remained normal.

The present findings may also provide important information with respect to future PAL design. The greater the clear field-of-view, presumably the more accurate and time-optimal is one's sensorimotor performance.[23] Although one option would be to wear SV lenses designed to have a wide and clear field-of-view for putting only at an intermediate distance, it would be less cumbersome and problematic to have a lens that was satisfactory at all golf distances, which would include a range from far (i.e., several hundred yards) to intermediate (i.e., the eye to ball distance during putting) distances. Furthermore, the same PAL could be used for the relatively infrequent near tasks at 40 cm or so, such as reading the scorecard. Thus, a multi-function PAL spectacle lens designed specifically for golfing and related tasks would be of great benefit to the serious golfer who is striving to obtain optimal conditions for maximum performance. If such a lens were available, it could reduce or eliminate the presence of undesirable astigmatism and distortion outside this zone, which create defocus and prismatic displacement effects. These factors might affect the determination of the "line" based on judgment of the cup's absolute distance and direction through this peripheral region. Thus, the improved PAL lens could reduce the visual/proprioceptive mismatch that would otherwise be present, thus leading to improved perception of these critical target location parameters.

CONCLUSION

This study quantified the effects of single-vision and progressive lenses on eye, head, and putter motions during the golf putting stroke. The wireless device provided a convenient means to measure these different factors simultaneously without subject-movement limitations. It was found that subjects wearing the progressive addition lens with the narrower intermediate zone (PAL2) exhibited slightly smaller eye movements than with the lens having a wider intermediate zone (PAL1). On the other hand, in apparent compensation for the restricted clear field-of-view, subjects wearing PAL2 exhibited greater head movements than PAL1. These findings have important ramifications in the design of PAL lenses for sports and in the workplace.

Dr. Hung has financial interest in the wireless sensor system used in this study.

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EDITORIAL CONTINUED

almost 4%. This can be interpreted as evidence that binocular difficulties are given somewhat more attention in the practice of primary care optometry than some have alleged.

The study lists the top 40 most frequent diagnoses that were reported. Not surprisingly, the basic refractive conditions and presbyopia accounted for almost 51% of the diagnoses. However, taken together, Accommodative Dysfunction, Refractive Amblyopia, Esotropia and Convergence Insufficiency accounted for 2.04% of the diagnoses. This is close to the 2.45% for the combination of Glaucoma Suspect and Open Angle Glaucoma.

It must be pointed out that the place of binocular vision disorders in the entire profession is not represented by the study; those in "specialized practice" did not meet the criteria for primary care optometric practitioners. Nevertheless, I interpret the report as indicating that, at least in terms of diagnostics, binocular vision disorders remain an integral part of primary care optometry. It is certainly not dead; rather, it is alive, but not kicking. The study should provide valuable information for the strategic planning of all organizations involved with the education of optometrists, and particularly for the Optometric Extension Program and the College of Optometrists in Vision Development.

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