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Maintenance of Skilled Performance With Age: A Descriptive Examination of Professional Golfers

Joseph Baker, Janice Deakin, Sean Horton, and G. William Pearce

Demographic studies indicate a remarkable aging trend in North America. An accurate profile of the decline in physical and cognitive capabilities over time is essential to our understanding of the aging process. This study examined the maintenance of skilled performance across the careers of 96 professional golfers. Data were collected on scoring average, driving distance, driving accuracy, greens in regulation, putts per round, and number of competitive rounds played using online data archives. Analyses indicate that performance in this activity can be maintained to a greater extent than in activities relying on biologically constrained abilities. Although the generalizability of these results to "normal" aging populations is not known, they suggest that acquired skills can be maintained to a large extent in the face of advancing age.

Key Words: master athlete, age-related decline, skill acquisition

Demographic studies indicate a remarkable aging trend in North American society. In Canada the number of adults over the age of 65 is expected to double by 2026 (Foot & Stoffman, 1996), and similar tendencies have been reported in the United States. Although this trend is primarily caused by aging baby boomers, in the past 160 years we have experienced an increase in average human life expectancy of approximately 3 months per year (Oeppen & Vaupel, 2002). Despite this finding, increased duration does not necessarily mean a life of higher quality. In fact, many aging adults risk spending a significant portion of their senior years in states of morbidity or complete dependence. Examinations of variables ranging from reaction time (Etnier, Sibley, Pomeroy, & Kao, 2003; Fozard, Vercruyssen, Reynolds, Hancock, & Quilter, 1994) to components of memory (Henry, MacLeod, Phillips, & Crawford, 2004), muscle strength (Kallman, Plato, & Tobin, 1990), and flexibility (Einkauf, Gohdes, Jensen, & Jewell, 1987) imply a downward spiral of functional ability with age.

Bortz and Bortz (1996) compared cross-sectional and longitudinal evidence for age-related decline in areas as wide-ranging and diversified as muscle-cell number (Lexell, Henriksson-Larsen, Wimblad, & Sjostron, 1983), rate of DNA

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repair (Wei, Matanoski, Farmer, Hedayato, & Grossman, 1993), and fingernail growth (Orentreich, Markovskyi, & Vogelmer, 1979) with cross-sectional data from running, rowing, and swimming and concluded that a decline of 0.5% per year was a general biomarker of the aging process. Although there is consistent evidence indicating that physical and cognitive capabilities decline *with* age, there is contradictory evidence as to whether this is actually *a result of* age. Maharam Bauman, Kalman, Skolnik, and Perle (1999) suggested that many of the factors thought to represent physical and cognitive declines associated with aging were in fact the result of a "long-standing sedentary lifestyle or disuse" (p. 274). Current thinking is that these two factors (i.e., disuse and declining performance) are inextricably linked.

Studies suggest that cognitive and motor performance can be maintained at high levels in spite of advancing age, provided there is continued involvement in the activity. For instance, Charness's (1981) study of chess players found that high levels of performance could be maintained as performers got older. Other examinations of cognitive-motor experts such as pianists (Krampe & Ericsson, 1996) and typists (Salthouse, 1984) substantiate these findings. These investigations point to the critical role that prolonged involvement (i.e., training) might play in maintaining performance.

An accurate profile of the decline in physical and cognitive performance over time is essential to our understanding of the aging process. The costs associated with longitudinal research, however, often preclude the systematic examination of age-related decline. Several researchers (Bortz & Bortz, 1996; Stones & Kozma, 1981, 1984) have suggested that masters athletes represent an ideal population for examining age-related decline because the comprehensive record keeping associated with many sports affords readily accessible measures of performance over time. Furthermore, data from masters athletes can be used to represent the performance levels possible if one maintains involvement in high amounts of physical activity throughout the life span.

Initial examinations of trends in athletic performance over time focused on track-and-field performers. In a series of studies, Stones and Kozma (1980, 1981, 1982a, 1982b, 1984, 1986a, 1986b) considered cross-sectional and longitudinal data of performance decline. Their analyses indicated that cross-sectional data show a more rapid rate of loss than was evident in longitudinal data. Furthermore, they found that the rates of performance decline varied across different track events, typically with greater loss occurring in events of longer duration, even when expressed relative to the distance of the event (Stones & Kozma, 1980, 1981, 1982a, 1982b). More recent research has corroborated these findings. Starkes, Weir, Singh, Hodges, and Kerr (1999) examined age-related decline in the 1,500-m and 10-km running times of masters track athletes. They contrasted the decline in performance times from age 20 to 60 using cross-sectional data on over 120 results per event with the longitudinal decline across the competitive careers of 12 masters track athletes. Their analyses showed a less dramatic and more linear deterioration for the longitudinal data, suggesting that the rate of loss might be overestimated when evaluating cross-sectional data. Our reexamination of their results to estimate the actual rate of deterioration yielded higher estimates of annual decline for the cross-sectional data (at 1%/year and 0.7%/year for the 1500-m and 10-km runs, respectively), as compared with the annual rates of decline for the longitudinal data on identical events (0.37%/year and 0.47%/year). The longitudinal results were remarkably consistent with the notion presented by Bortz and Bortz (1996), suggesting a consistent rate of loss in physical and cognitive capabilities in the range of 0.35–0.5% per year.

Although this range of performance deterioration is consistent, these domains rely heavily on physiological or biological parameters. In contrast, sports in which performance is largely determined by cognitive and motor proficiency might be more resistant to age-related declines. The sport of golf provides an optimal source for the study of performance and aging over time for several reasons. First, golfers tend to peak later than athletes in sports based on strength, power, and speed (Schultz & Curnow, 1988), suggesting that performance in this domain might be less constrained by biological factors and more reliant on acquired skills. In addition, golf has objective markers of performance and the careers of elite golfers often last for decades.

In a recent study (Baker, Horton, Pearce, & Deakin, 2005) we examined the performance of 17 elite professional golfers whose performance spanned the Professional Golfers Association (PGA; open to all ages) and Champions (open to players age 50 years and older) Tours. All golfers met the criteria of having played an average of at least 30 tournament rounds per year from age 35 to 60 on either tour and having won at least five tournaments on the Champions Tour. Regression analyses of scoring average (mean number of strokes to complete 18 holes of golf) on age yielded an annual rate of decline in performance of 0.07% when competing on the PGA Tour and a rate of decline of 0.25% while competing on the Champions Tour. Despite the accelerated rate of performance decrement from age 51 to 60 years, at no time did these golfers approximate the rate of decline predicted by Bortz and Bortz (1996). Nonetheless, there were some limitations with this work. First, the sample size was quite small, therefore limiting the nature of the analyses and comparisons that could be made. Second, the only performance outcome examined was scoring average, which, although arguably the best measure of golf performance, is a composite of other performance measures. Given the stability in performance as measured by scoring average for this highly select group of golfers, we were interested in examining a larger range of performance indicators across a more diverse selection of elite golfers to determine whether different patterns between age and performance would emerge. Specific research questions under examination included the following: What is the age of peak performance for various golf skills? What is the relationship between age and performance in the PGA-Tour golfers? Does the age-related decline vary among the different components of golf performance? What is the relationship between competitive rounds played and age-related decline in golf performance?

Method

All data for the study were collected from the official Web site for the PGA Tour (www.pgatour.com). This official archive provides reliable golf-performance data that can be examined over time. The first year for which online summary statistics were available was 1980, and we selected our cohort of golfers from 1985 in order to minimize edge effects but still allow ourselves a reasonable longitudinal time frame. In addition, we limited our sample to those who had played on the Tour for a minimum of 12 years. This permitted a sufficiently large sample and yet ensured that the players were established and consistent performers on the Tour. Of the 158 players listed as active on the PGA Web site in 1985, 96 met our criteria and had complete data available. Comparison of this sample with all players on the PGA tour in 1985 indicates that our sample was a good representation of all players on the Tour in that year (e.g., scoring average, our sample = 71.9, whole tour = 71.7; driving distance, our sample = 260.3, whole tour = 262.6; putts per round, our sample = 29.7, whole tour = 29.6).

Annual summary data for each of the selected players were collated beginning with the 1980 season. Performance indicators examined included

- Scoring average: the average total number of strokes required to complete an 18-hole round of golf
- Driving distance: the average number of yards per measured drive
- Driving accuracy: percentage of time a golfer's drive landed in the fairway
- Greens in regulation: the percentage of time a player was able to hit the green in regulation (greens hit in regulation or holes played), determined by the golfer's ability to hit greens on a par-5 hole in three strokes or less, greens on a par-4 hole in two strokes or less, and greens on a par-3 hole in a single stroke
- Putts per round: Average number of putts taken per 18-hole round played
- Rounds played: number of competitive 18-hole rounds (i.e., PGA rounds) played during the year

Performance was considered both as an absolute measure and relative to all other players on the Tour (i.e., relative rank); however, ranked data were incomplete for 19 of the 96 players. As a result, only the ranked data of 77 players were included in these analyses.

Statistical Analyses and Data Reduction

The data set would seem well suited to a repeated-measures design with year of birth as a covariate and age (with 25 levels) as the repeated factor. Because of the period for which we have data, however, some players were not represented when they were young and some not when they were older. The sample was too sparse (i.e., as a matrix) for the repeated-measures design unless we used a small subset of our sample. In addition, the general linear-model technique did not take into account the equipment- and technique-driven improvements to the PGA field as a whole. If the change were known to be linear it could have been incorporated as a covariate in the analysis, but the degrees-of-freedom deficit would then be worse. The method we used was to consider data from the entire PGA field during the time period we sampled to estimate the secular trend for the field. We corrected the individual player scores according to how each player would have benefited from these external factors. For example, if a player had an average distance gain of 10 yd over 10 years, but the PGA field improved by 15 yd over the same period, the player has a net loss of 5 yd. The corrected data allowed more accurate comparisons of the variables for individual players at the same ages. We could then average all player records for each age from 25 to 50 years to produce averaged parameters for the group. These averages would include almost all players in the middle years and fewer toward younger and older ages. The data could then be statistically analyzed through linear regression to determine trends. These regression curves represent almost our entire group in the middle years, with drop-off in numbers at the ends.

Based on the preceding description, statistical analyses progressed in a series of steps. The first step involved examining the raw (i.e., uncorrected) performance data from 25 to 50 years of age for the study outcomes. In Step 2, secular trends in the PGA field performance were examined to determine the nature of the corrections to be made to the data for each player. The decrease in rank for the selected set of golfers is often not congruent with their absolute performance values. Most notably, driving-distance rank consistently declines and absolute driving distance increases. These findings may be the result of advancement of the average performance of the field over time (Chatterjee, Wiseman, & Perez, 2002). To reconcile these discrepancies, we examined the changes in overall Tour performance throughout the time span considered in this study. These data were also available on the PGA Web site, and average parameter values per year are shown in Figure 1.

All parameters suggest an increase in mean proficiency over time, with the exception of driving accuracy, which shows a downward trend in the most recent 3 years. The dramatic improvement in mean Tour scoring average after 1986 is the result of a change in the manner in which scoring average is calculated by the PGA Tour. (In 1988 the formula to compute scoring average was changed to reflect course difficulty. Before 1988, it was computed as a pure average.) Thus, there can be no direct comparison between scoring averages before and after this date. As a result, golfers with performance data before 1986 will slightly misrepresent the results for early ages. This misrepresentation was removed by deleting all data before 1986 from the golfers' statistics. Mean Tour driving distance hovered around 260 yd until 1993, after which it increased in a linear fashion, reaching an average of 287 yd per drive in 2004. This dramatic increase can be attributed primarily to improvements in equipment technology. Our selected set of golfers benefited from these improvements, but at different ages. As a result of the range of ages at which they benefited, the absolute performance comparisons computed in the previous section might not provide the most accurate examination of the aging process. This obstacle can be partially removed by applying a correction to the driving-distance data for each golfer according to his age for each year. Secular changes also occurred for driving accuracy, greens in regulation, and putts per round and were corrected in a similar fashion. Finally, corrected performance data across the 25- to 50-year age period were examined.

Results

Scoring Average

Data for scoring average are presented in Figure 2. All the figures have two *y* axes, with absolute data presented on the left and ranked data on the right. After an initial improvement in raw scoring average, our cohort of golfers remains relatively constant from age 28 to 43 and then shows deterioration in performance from a score of ~72.0 to 73.5 by age 50. Their relative rank, however, deteriorates after age 36 or 37—the increase in mean rank is from ~60 to ~100. The corrected data

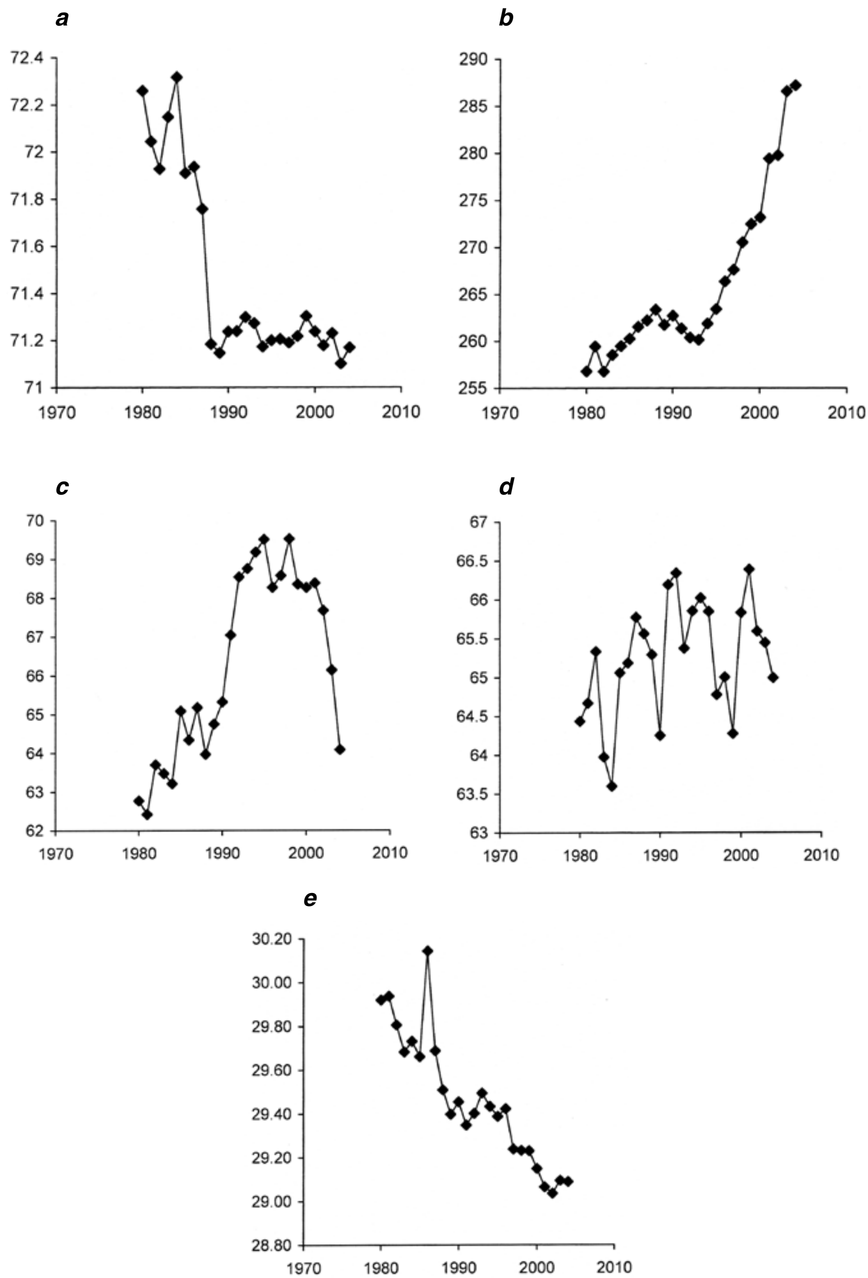

Figure 1 — Change in overall tour performance on (a) scoring average, (b) driving distance, (c) driving accuracy, (d) greens in regulation, and (e) putts per round over time for the selected sample of golfers.

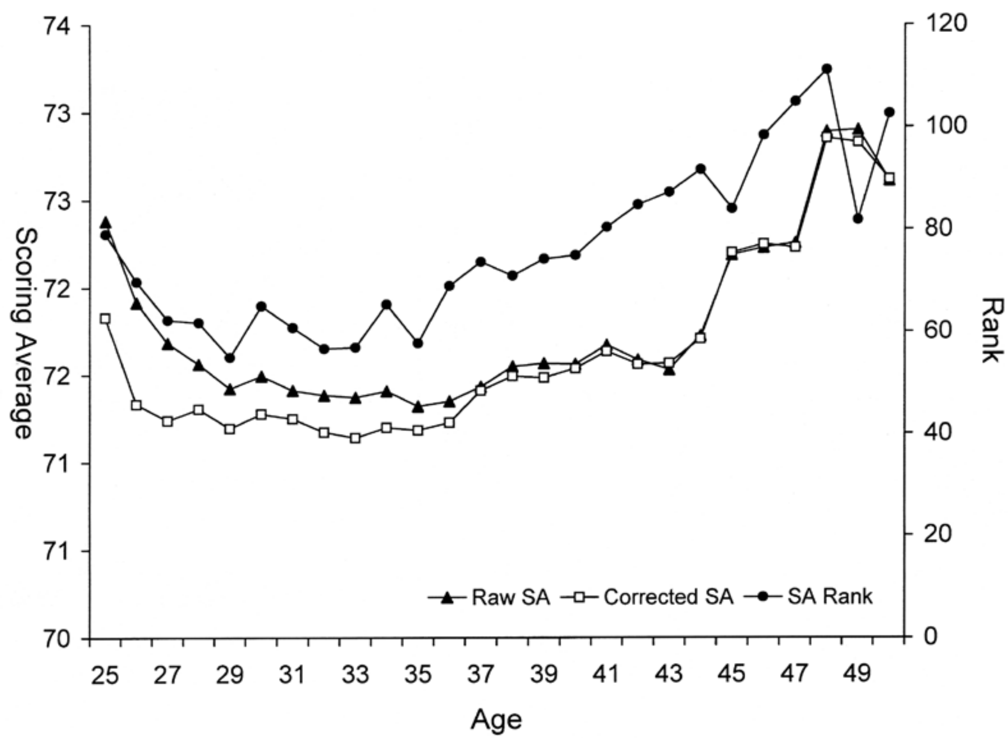

Figure 2 — Raw and corrected scoring average (SA) and scoring-average rank by age for the selected sample of golfers.

follow a profile similar to that of the raw data except for lower scores during the first 10 years of Tour play. The mean annual decline in scoring average after a period of stable peak performance (age 31–36) was 0.14% (± 0.01%) per year. Standard deviations indicated an increase in variability with advancing age for raw (range = 1.37 at 25 years to 1.96 at 50 years) and corrected scoring average (range = 0.64 at 25 to 1.99 at 50), as well as scoring-average rank (range = 41.77 at 25 to 72.90 at 50).

Driving Distance

Driving-distance data are presented in Figure 3. The golfers as a group decreased their raw average driving distance in their 20s to reach a level value of about 260 yd. They then showed a roughly linear increase yearly to 265 yd at 45 before falling back to 260 yd by 50. In contrast, their rank worsened continually throughout their careers. Although the raw data indicated an improvement over time, with golfers peaking at the age of 45, when these data were corrected for overall Tour performance there was a substantial drop in relative performance (M = 0.23% ± 0.01% per year from peak performance at age 28) and hence the large drop in ranking. Variability in driving distance (i.e., *SD*) showed a general increase with age, with the exception of the ranked data, which had high variability across the measurement period (raw driving-distance range 7.64 at age 25 to 13.74 at age 50, corrected driving-distance range 7.64 at age 25 to 11.67 at age 50, and ranked-data range 46.80 at age 25 to 52.50 at age 50).

Driving Accuracy

Raw data for driving accuracy show an increase in performance until approximately age 39 followed by a period of relative stability until age 49. Relative rank remains relatively stable throughout the golfers' careers. Similarly, the corrected data remain relatively stable over time (rate of decline = 0.03% ± 0.03% per year). A profile of these data is presented in Figure 4. Standard deviations for raw and corrected driving distance were relatively low but appeared to increase slightly over time (range from 6.57 at age 25 to 8.74 at age 50 for raw data and from 6.72 at age 25 to 9.27 at age 50 for corrected data). In contrast, variability in the driving-accuracy ranks remained relatively high throughout the age range studied (range 47.0 at age 25 to 49.2 at age 50).

Greens in Regulation

Raw data for greens in regulation (Figure 5) indicate an increase in the percentage of greens hit in regulation to age 29 followed by a period of relative stability from age 30 to ~37. After age 37 there is a consistent decrease in the greens hit in regulation. In contrast, there is a relatively stable deterioration in relative rank with advancing age from approximately 40 years of age. The corrected data for greens in regulation remain similar to the raw values, with a general rate of decline of 0.36% (± 0.04%) per year after a period of relatively stable peak performance (age 33–38). There was an increase in variability with advancing age for raw and corrected greens in regulation (raw-data range 3.67 at age 25 to 6.74 at age 50, corrected-data range 3.68 at age 25 to 7.55 at age 50), as well as greens-in-regulation rank (range 51.08 at age 25 to 63.08 at age 50).

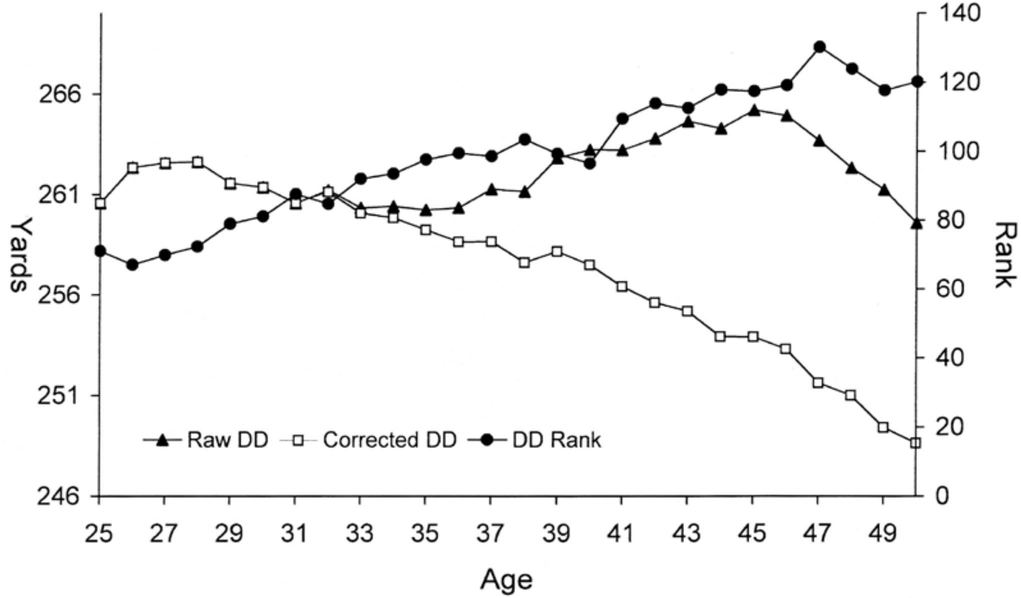

Figure 3 — Raw and corrected driving distance (DD) and driving-distance rank by age for the selected sample of golfers.

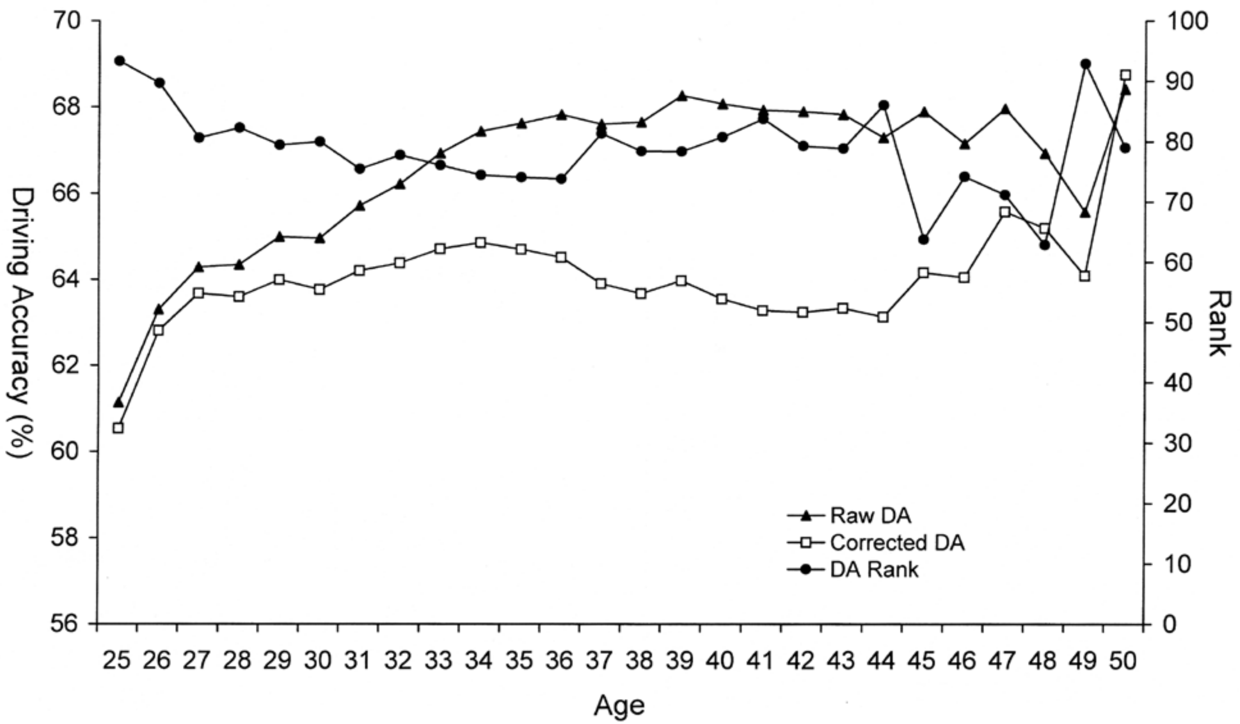

Figure 4 — Raw and corrected driving accuracy (DA) and driving-accuracy rank by age for the selected sample of golfers.

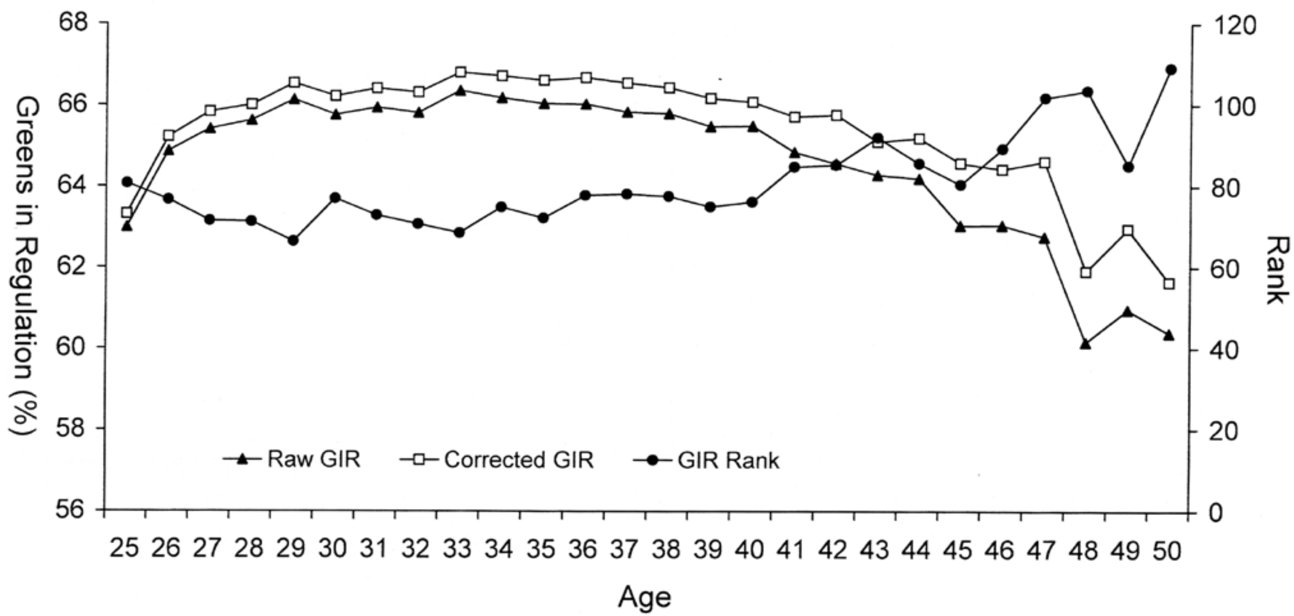

Figure 5 — Raw and corrected greens in regulation (GIR) and greens-in-regulation rank by age for the selected sample of golfers.

Putts per Round

Data for putts per round are presented in Figure 6. There is a slow and steady deterioration in absolute performance and rank after age 30, with the exception of the data points representing ranks at age 35, 49, and 50. Although the rationale for the improvement in rank at age 35 is not clear, it might be that performance improvement at ages 49 and 50 reflects increased training/involvement to prepare for the Champions Tour. Corrected data indicated a general rate of decline of 0.11% (± 0.02%) per year from peak performance at age 35. This slower rate of age-related decline might explain the less precipitous drops in ranking previously demonstrated for putting. Standard deviations also showed an increase with advancing age (raw-data range 0.59 at age 25 to 1.39 at age 50, corrected-data range 0.58 at age 25 to 1.18 at age 50, ranked-data range 45.94 at age 25 to 60.60 at age 50 for ranked data).

Relationship Between Scoring Average and Tournament Rounds Played

Figure 7 illustrates the relationship between number of rounds played on the PGA Tour each year and loss in performance. The relationship illustrated suggests three stages in the careers of the golfers in this sample. Number of rounds played increased until around 30 years of age, coupled with an improvement in performance. This is followed by a consistent decrease in competitive involvement until age 49, at which point the number of rounds increases again. During this period (i.e., from age 30 to 49), performance was maintained until age 43, after which it began to decline. This decline continued relatively consistently from 43 to 50 years of age.

Discussion

Results from the current study indicate a decline in golf performance in the face of advancing age. The rate and profile of decline, however, depended on the skill under consideration. Greens in regulation and driving distance had the greatest rates of decline from the age of peak performance until age 50 years, diminishing at a rate 0.36% and 0.23% per year, respectively, compared with 0.14% and 0.11% for scoring average and putts per round, respectively. Driving accuracy showed a small improvement in performance over the same period (0.03% per year). Driving distance also peaked at an earlier age than scoring average and putts per round. The greater rate of decline in driving distance is perhaps not unexpected because driving distance is the metric of performance most closely associated with muscle power. Previous work (Schultz & Curnow, 1988) has suggested that muscle power peaks earlier and declines more rapidly than motor skills that demand less power.

Despite the variability in rates of decline among the measures examined in this investigation, none approached the annual rate of 0.5% suggested by Bortz and Bortz (1996) to be a general biomarker of the aging process, although the rate for greens in regulation was relatively close (0.36%). Furthermore, these findings corroborate previous research (Starkes et al., 1999; Stones & Kozma, 1982a) indicating considerable differences in rates of decline between cross-sectional (i.e., Bortz & Bortz) and longitudinal (e.g., the current study) data sources. The current

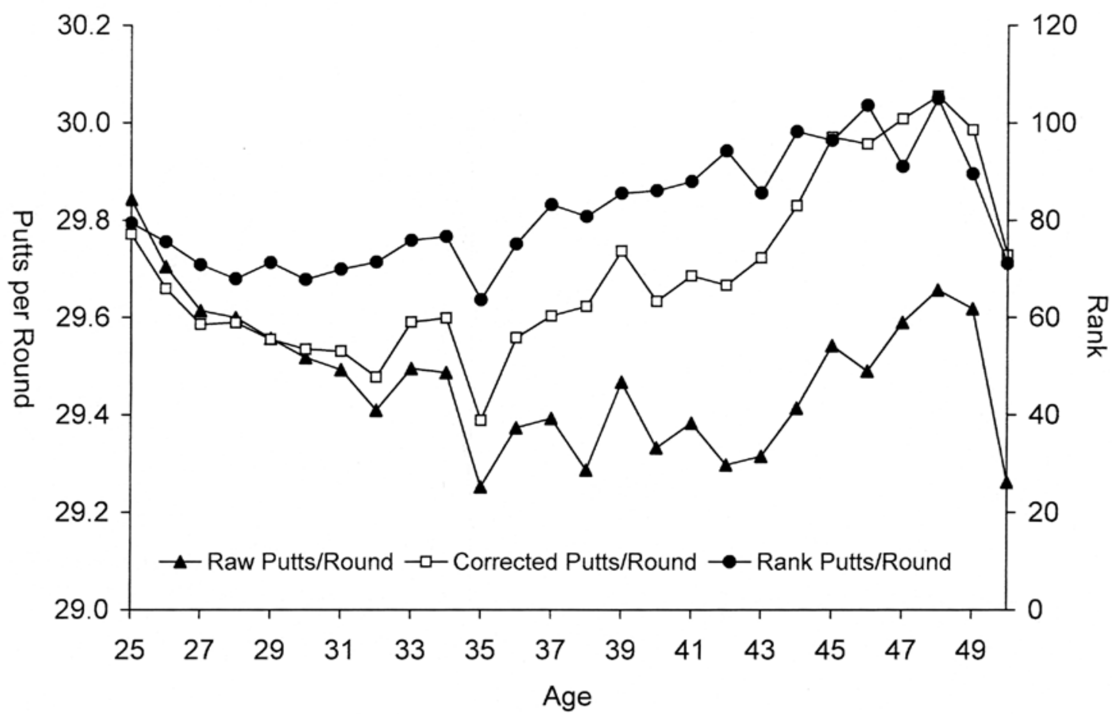

Figure 6 — Raw and corrected putts per round and putts-per-round rank by age for the selected sample of golfers.

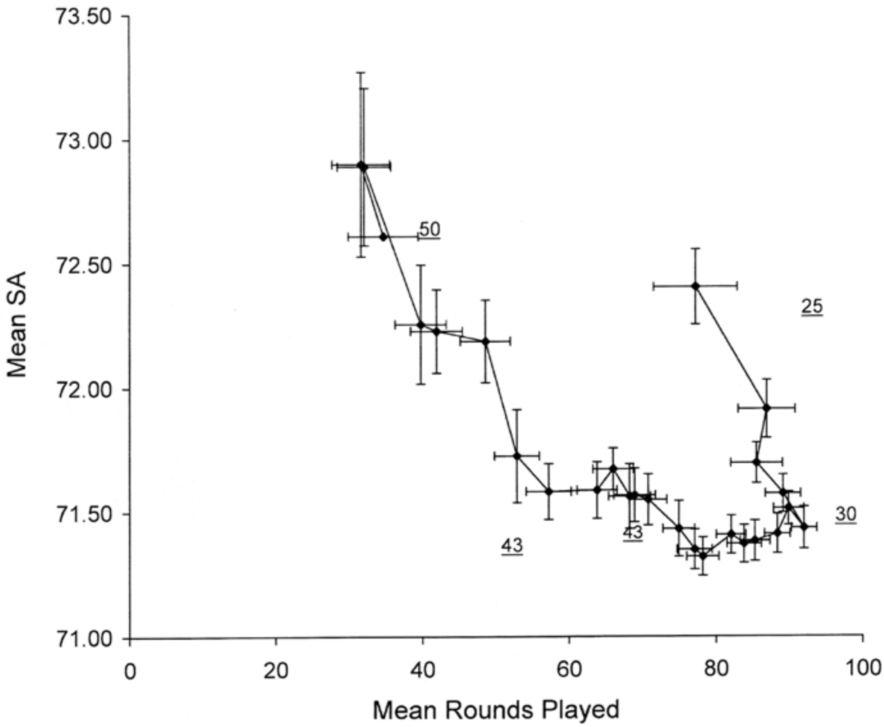

Figure 7 — Relationship between tournament rounds played and scoring average (SA) from age 25 to 50 for the selected sample of golfers (error bars represent standard errors). Ages where key changes occur have been noted.

findings suggest that golf might be more closely aligned with cognitive-motor activities such as chess and piano (Charness, 1981; Krampe & Ericsson, 1996) than it is with sports constrained by physiological factors such as aerobic capacity. Sports involving skills that require a finer degree of motor control, necessitating a longer period of acquisition, appear to be more resistant to age-related decline than physiological capacities.

Although these results corroborate previous findings from other areas of skilled performance, alternative explanations might also apply. For instance, the difference in the rates of decline between Bortz and Bortz (1996) and our results might be a result of differences inherent in cross-sectional versus longitudinal designs. Specifically, cross-sectional data might represent performance by athletes with a broader range of ability, whereas longitudinal data might represent individuals who were simply better, more capable performers.

Although these findings might indicate that skilled golf performance is more stable over time than performance in other sports, the role that training (i.e., deliberate practice; Ericsson, Krampe, & Tesch-Romer, 1993) plays in this relationship is unclear. In these golfers performance was maintained, to a large degree, despite decreasing involvement in competition (i.e., number of tournament rounds played). Despite the reported importance of time spent in competition in other sports (Baker, Côté, & Abernethy, 2003), however, competitive rounds might not be a good proxy for involvement in golf. Detailed accounts of practice quantity and quality would do much to illuminate this issue.

The relationship between competitive rounds played and scoring average (arguably the best metric of overall performance) suggests a three-stage progression across the PGA career of a professional golfer. The first stage, from 25 to 30 years of age, is demarcated by increasing involvement in competitive play coupled with a dramatic improvement in performance. Examinations of learning profiles from many domains (see Newell & Rosenbloom, 1981, for a review) support the strong positive relationship between initial involvement in a domain and rapid increases in overall performance. From 30 to ~43 years of age there is a consistent decline in the number of rounds played on the PGA Tour; however, the players essentially maintain their performance. There are a number of possible explanations for this effect. First, players have decreased involvement in all forms of golf, and overall performance is maintained for years despite this reduction. Second, the players have decreased involvement in tournament play but maintained (or increased) time spent in practice, which allows performance to be maintained. Finally, the golfers have maintained performance through the use of compensatory mechanisms (i.e., players balance losses in some aspects of their game by compensating in others).

The use of compensatory adaptations is one of the most widely supported explanations for the maintenance of skilled performance over time (Bäckman & Dixon, 1992). Although there are several theories of compensation (c.f. Baltes & Baltes, 1980, 1990; Salthouse, 1987, 1990), a common aspect is the notion that although individual components of a skill might decline with age, it is possible for overall performance to remain the same because of an increased reliance on other aspects of performance. Put more simply, the theory suggests that skilled performers strategically compensate for a decline in one area by developing or improving in another. In golf terms, a player's course management might improve to offset declines in other areas. As tournaments are often played at the same course year after year, increasing familiarity with the nuances of the layout (e.g., driving strategically to afford the easiest approach into the green) could potentially compensate for a loss in driving distance.

The current study considered several interdependent measures of performance and as a result might provide some data regarding the use of compensatory mechanisms to maintain golf skill. Nonetheless, these data indicate that even if compensation occurred it was unable to preserve the balance as the athletes reached their mid-40s. The pattern of decline over time in four of the five study variables does not support the compensation view; however, the slight increase in driving accuracy suggests that compensation in some areas might underlie the low rates of decline in golf performance. For instance, golfers might compensate to a certain extent for decreases in driving distance by having drives that are more accurate. Researchers are encouraged to consider the role of compensation in other golf performance variables, as well as other types of performance, to confirm these findings. It is also important to acknowledge the interconnectivity of the variables examined in this study. For instance, a decrease in greens in regulation might lead to fewer putts, provided that a player's pitch or chip shot is hit close enough to the hole to allow for a one-putt green. In this sense, a player might compensate for hitting fewer greens in regulation through an improved short game. Future research is also needed to confirm the value of competitive rounds as an accurate proxy for overall involvement.

The period from age 43 to 50 (Stage 3) is demarcated by a continuing decline in the number of competitive rounds; however, now there is also a corresponding decline in performance. If tournament rounds are a reasonable approximation of overall involvement, these data suggest that golf performance can be maintained for an extended period despite reductions in involvement (Stage 2), but eventually performance will decline as seen in Stage 3.

These findings also highlight the need to consider specific contextual factors that might confound longitudinal examinations of skilled performance. There is consistent evidence indicating that domains continue to evolve over time, particularly in sport (Chatterjee et al., 2002; Chatterjee & Yilmaz, 1991, 1999), and although sport records provide an excellent avenue for tracking athlete performance with age, it is critical that researchers control for advances in the mean performance of the field of comparison. Enhancements in technology, whether in the form of better equipment, superior training techniques, or more advanced ergogenic aids, could lead to misinterpretations of the aging profile. An excellent example in the current study is driving distance. The raw data gave the impression that driving performance improved with age, but after controlling for the improvement in the field we find a more accurate age-related profile of this performance measure.

Future research is needed to build on this work while correcting for possible limitations of the current methodology. The role of actual time in practice would add further depth to our understanding of performance and age. Furthermore, the nature of the data set used in this study precluded the use of conventional statistical techniques, and further examination of these research questions using data more conducive to repeated-measures designs would be useful. Finally, data for this study were collected from a very elite sample of athletes who have taken part in decades of intense training and competition. As a result, the generalizability of their results to "normal" populations is assumed rather than proven. Investigations of the age-related decline in performance for complex, everyday skills (e.g., driving a car) might provide insight into how well results from the present study describe the general profile of the decline in skilled performance with age. Such research would prove extremely valuable for informing policy decisions for our aging population.

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