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Knee biomechanics during popular recreational and daily activities in older men

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ABSTRACT

Background: Physical activity is recommended for older adults, including those with knee pathology. However, demands on the knee during popular recreational activities are unclear. The study purpose was to determine knee biomechanics in healthy older men during golf and bowling and compare them to activities of daily living.
Methods: Three-dimensional motion analysis was used to determine knee biomechanics in 19 healthy males (45–73 years): 11 golfers and eight bowlers. Subjects performed walking, stair ascent, stair descent, and either golf or bowling. Comparisons were made between the recreational activity and activities of daily living.
Results: During bowling, flexion angle at peak extensor moment was as high as during stair descent, and peak extensor moment was as high as during stair ascent. For the golf lead knee, flexion angle at peak extensor moment and peak extensor moment were as high as during stair ascent, and peak abduction moment, internal and external rotation angles were larger than during all activities of daily living. Peak external rotation angle for the golf trail knee was larger than all activities of daily living.
Conclusion: The greatest challenge for the knee of healthy older males during bowling is eccentric control of knee flexion. Golf poses challenges in all three planes of motion for the lead knee and in the transverse plane for the trail knee.
Clinical relevance: Comparing mechanical demands on the knee during bowling and golf to those of stair negotiation provides a reference for clinicians when recommending recreational activities for older adults with knee pathology.

1. Introduction

Physical activity is an important means of preventing weight gain and improving cardiovascular health and physical function, especially among older adults [1,2]. For older adults, the American College of Sports Medicine recommends at least 30 min of moderate-intensity aerobic activity five days a week or 20 min of vigorous-intensity aerobic activity three days each week [2]. However, chronic conditions may prevent these levels from being reached. The Physical Activity Guidelines for Americans recommend that older adults with chronic conditions should be as active as their abilities allow [3]. Physical activities that are considered purposeful or fun and help maintain socialization are motivating factors for older adults to be physically active [4]. Therefore, social recreational activities may help increase physical activity participation among older adults with knee pathologies. However, the biomechanical demands placed on the knee of older adults during popular recreational activities have not been reported in the literature.

Given the focus on increasing recreational physical activity in older adults with knee pathology, investigation of knee biomechanics in those activities should focus on variables known to be affected by knee pathology. In particular, those biomechanical variables which are known to be affected by knee pathology during daily activities should be the focus of investigations into recreational activities. We focused on knee biomechanical variables that differ from healthy older adults during walking in adults with total knee replacement (TKR), a common surgery for end stage knee pathology in older adults. A common finding is that older adults with TKR exhibit a smaller knee flexion range of motion over the entire gait cycle compared to healthy older adults [5–7]. Several studies also indicate a smaller peak knee flexion angle during loading in older adults with TKR compared to healthy controls [8,9]. To aid comparison across different activities, knee flexion angle at peak internal knee extensor moment may be useful to reflect the challenge placed on the knee. Peak internal knee extensor moment is also smaller in older adults with TKR compared to healthy controls [10,11]. Differences in the secondary planes of motion during walking have also been reported. Recent literature reporting first peak internal knee

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abduction moment is conflicting, with either a smaller first peak internal knee abduction moment compared to healthy controls [11–13], or no difference [14]. Older adults with TKR also have a smaller peak knee internal rotation angle, but larger peak knee external rotation angle during walking compared to healthy controls [9]. Overall, peak joint angles and moments in all three planes of motion differ during walking in older adults with TKR compared to healthy older adults. Thus, the magnitude of these variables during recreational activities in older adults is of interest in relation to physical activity recommendations.

Golf and bowling are popular social recreational activities among older adults [15–17]. Among healthy older adults, golf is the fourth most frequent leisure time physical activity [17]. Knee biomechanics during golf have been reported for healthy younger adults [18–20] and adults with TKR [21,22] but not for healthy older adults. Furthermore, knee biomechanics during bowling have not been reported. Thus, the first step in developing evidence-based physical activity recommendations for older adults with knee pathologies is to identify how peak magnitudes of knee biomechanical variables differ during these activities compared to daily living activities in healthy older adults. The development of such evidence-based physical activity recommendations would provide guidance to clinicians in suggesting physical activities for patients with knee pathology.

Therefore, the purpose of this study was to determine knee joint kinematics and kinetics in healthy older men during a golf swing and during bowling. In addition, knee biomechanics during these recreational activities were compared with walking, stair ascent, and stair descent. This study focused on those variables commonly altered during walking in older adults with knee pathology, specifically TKR. We hypothesized that knee flexion range of motion, knee flexion angle at peak internal knee extensor moment, peak internal knee extensor moment, peak internal knee abduction moment, peak knee internal rotation angle, and peak knee external rotation angle during bowling or golf would be different in each recreational activity compared to the activities of daily living.

2. Participants

Nineteen men between the ages of 45 and 75 years who were either golfers ($n = 11$) or bowlers ($n = 8$) participated in this study (Table 1). All golfers were right handed and four of eight bowlers were right handed. Participants were recruited from area golf courses, bowling alleys, and senior citizen centers. All had been participating in their recreational activity at least twice a month in season for the past year. Participants were currently injury free, reported no lower extremity injuries within the past 6 months, and had no history of joint replacement. Exclusion criteria were self-reported symptomatic lower extremity arthritis, current pain, inability to understand and follow instructions, and inability to negotiate stairs in a step over step manner without the use of a handrail. All participants provided written informed consent before commencing the study. The study was approved by the University's Institutional Review Board.

Table 1
Participant characteristics.

	Golfers	Bowlers
Age (yr)	57.7 ± 8.5 (45.0–73.0)	58.6 ± 10.3 (46.0–69.0)
Height (m)	1.80 ± 0.07 (1.66–1.88)	1.78 ± 0.08 (1.67–1.92)
Mass (kg)	95.9 ± 14.5 (62.7–113.2)	86.3 ± 8.4 (70.7–95.2)
Body mass index (kg/m^2)	29.93 ± 5.9 (18.72–41.08)	27.3 ± 3.2 (23.62–33.10)
Average score	82.8 ± 6.8 (74.0–95.0)	189.7 ± 34.3 (128.0–225.0)
Participation per week (h)	12.0 ± 5.3 (6.0–24.0)	5.0 ± 2.5 (2.0–9.0)
Total experience (yr)	41.7 ± 10.1 (25.0–55.0)	33.1 ± 21.5 (1.0–55.0)

All values are given as the mean ± standard deviation (range).

3. Methods

Three-dimensional position data were collected at 240 Hz using a nine-camera motion capture system (VICON, Oxford Metrics, Oxford, United Kingdom). Two AMTI force platforms (American Mechanical Technology Inc., Newton, MA) synchronized with the motion capture system were used to collect ground reaction force data at 1200 Hz. Retroreflective markers were attached bilaterally to the following anatomical landmarks: the iliac crests, the greater trochanters, the medial and lateral femoral epicondyles, the medial and lateral malleoli, and the base of the first and fifth metatarsal heads. Rigid thermoplastic shells affixed with a cluster of four markers were attached to the sacrum, thighs, and shanks to track the body segments during the dynamic trials [23]. Three tracking markers were also attached to the posterior and lateral calcaneus to track the foot. Additionally, markers were placed on the radial styloid process, the lateral humeral epicondyle, and the posterior forearm of the dominant side of the golfers. These markers were used to determine the start and end of the golf swing. Tracking markers remained in place for all conditions. A static trial was collected with the participant standing on a standardized template on the force platform [24]. Anatomical markers were removed after the static trial.

Data were collected while participants performed walking, stair ascent, stair descent, and either golf or bowling. Participants wore standard laboratory footwear during all conditions (BITE sandals) [25]. Shoe type has been shown to have no effect on peak knee forces and moments during a golf swing [18]. The order of presentation of experimental conditions was randomized using stratified randomization. The stair negotiation, walking, and recreational activity conditions were randomized with stair ascent and stair descent being randomized within the stair negotiation stratum. Following a familiarization period, participants walked the length of a 10 m walkway at a self-selected velocity. Walking velocity was monitored using two photo cells placed 3 m apart and a timer. The right limb was of interest during walking. Five successful trials were collected.

A 3-step instrumented wooden staircase (FP-Stairs, American Mechanical Technology Inc., Watertown, MA) and a 2-step independent wooden structure were used for stair negotiation trials. The instrumented staircase consisted of three steps, each with an 18.5 cm rise, 60.5 cm width, and 33.0 cm depth. The three steps of the instrumented staircase were rigidly and independently attached to the two force platforms. A railing was attached to the right hand side of the staircase and the back of the top step, which extended into a platform. Participants ascended and descended the stairs in a step over step manner without the use of the handrail. Participants contacted the third step with the right foot for both stair ascent and stair descent. Stair negotiation velocity was monitored using photo cells centered on the third step and timers. Participants walked at a self-selected velocity during both stair negotiation conditions. Five successful trials were collected for both stair ascent and descent.

Golfers performed five successful golf drives using an indoor golf practice mat and their own driver. Participants stood with one foot on each of the two force platforms. A piece of artificial turf was attached to each force platform to simulate the surface of an outdoor course. A practice mat was placed at a comfortable distance in front of the golfer. A practice golf ball on a tee was attached securely to the practice mat via a short cord. Golfers were instructed to hit the ball in a similar manner as driving a straight ball from the tee on a par four hole. This laboratory configuration is similar to previous studies of golf [18,19]. Golfers chose their preferred stance for the swing. Practice swings were allowed until the golfer felt comfortable with the motion and could hit the ball consistently. Both the lead and trail limb were of interest.

Bowlers performed five successful trials on a simulated lane using their own bowling ball. A shortened rubberized bowling lane was constructed in the laboratory to provide a target and also contain the bowling ball. Foam bowling pins were set up in a regulation formation 6.5 m from the front of the force platform. The laboratory floor was marked in