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Subjects' Ability to Characterize g's in Relation to Activities of Daily Living

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Abstract

The amount of force associated with a specific activity or event often utilizes g's (g-force) and the unit of force. In litigation, biomechanics forensic experts provide general causation analysis of injury events, referencing the g's of the event and often the g's associated with Activities of Daily Living (ADLs). It is assumed that jurors will understand and correctly interpret any presented g values. This research explored the validity of this assumption. A survey instrument was employed that included 610 subjects to probe an individual's understanding of what g's are and their beliefs of the associated magnitude of ADL g's. The results indicated that most adults have a limited understanding of g's, often holding incorrect beliefs. For example, many believe they do not experience 2 or 3 g's during daily activities. Therefore, it is useful for the engineering expert to frame g-based analysis with references to ADLs, providing individuals (and jurors) with a proper framework to understand the analysis results. Without such reference points, jurors may misunderstand — and attorneys can misrepresent — the meaning of any g's associated with the specific case analysis.

Keywords

Activities of Daily Living, ADLs, biomechanics, g's, forensic engineering

Introduction and Background

In the analysis of injury-related events, such as vehicular collisions, falls, blunt trauma, etc., the unit of force often adopted is "g's" (or g-force). In the case of a vehicular collision, the reported g's may refer to the vehicular collision force experienced by any occupants within the vehicle. Regarding blunt trauma on the body due to an object, it would reflect the force of impact on the body due to the delivery of force by the object. Such a convention normalizes force references in that only the acceleration term from the equation F = ma is considered.

For reference, 1 g is the force of gravity. Therefore, an object's weight on the surface of this planet would be mass of the object X 1 g (using appropriate values and units). With the gravity = 1 g reference, 2 g's could be interpreted as twice the force of gravity, and so on. In addition, in the field of biomechanics, it may be difficult to determine what the "m" is. For example, in cervical injuries (where the head acceleration may be estimated in g's), it is challenging to determine if the mass is the head only, the head-neck, etc. In shoulder biomechanics, it is unclear what the mass of the "shoulder" should be in an F = ma type calculation. Thus, using g's is a common protocol in biomechanics.

People have some awareness of g's as a unit of force. For example, roller coaster rides are often reported in terms of g's (current roller coasters now approach 6 g's)[1], with higher values indicating more of a "thrilling" ride for roller coaster aficionados. The force experienced by jet pilots may be reported in terms of g's — with values sometimes approaching 9 to 10 g's. Also, many know the "zero gravity" type environment that individuals in outer space experience. There appears to be no published research on an individual's awareness of 1 g, 2 g's, 3 g's, etc. regarding day-to-day activities or any other references — whether from a psychology or a scientific literacy viewpoint. For most, g-force familiarity is attributable to the "pop culture" examples such as those cited above.

In analyzing a specific injury event, a forensic engineering expert may report that the injury event of interest resulted in 2- to 3-g force exposure (the range indicating any uncertainties that may be present). This is very common in the vehicular accident reconstruction — where the reconstructionist may report the delta-V (change in velocity) in velocity units and the associated vehicle acceleration in g's.

In the injury biomechanical analysis of the same

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event, the occupant's force exposure is often reported in g's — sometimes applying different g values to different body regions. For example, the head acceleration may be reported as 5 g's, the lumbar region as 3 g's, etc. The reported values may reflect "average acceleration" (average g's) or "peak acceleration" (peak g's) — testifying experts may not always make this distinction clear. As part of the analysis, the biomechanics expert may cite literature that investigates injury-causing events (sometimes involving human subjects) or other force applications resulting in a specific injury where the reported force values are often in g's. For example, in human head injury tolerance analysis, the injury thresholds are often presented as a combination of head acceleration in g's and exposure time[2].

In the utilization of g's as the unit of force, there may be an assumption on the part of the reader (or juror) that the individual actually has accurate knowledge of how to interpret g's. As noted above, there is no actual research on the validity of this assumption in terms of the general population and subsets of the general population (demographics such as education level, age, etc.). This manuscript reports a human subject study where this question was posed. More specifically, this investigation probed if individuals had any understanding of g's in general as well as in terms of what an average human actually experiences in their daily lives. The results of such a study could provide insights into the possible utilization of references of g values associated with so-called ADLs and how such references could assist in ensuring that individuals had some reference points to properly understand and interpret g values.

Activities of Daily Living (ADLs)

ADLs refer to activities that most people might perform during a typical day, such as sneezing, coughing, vehicular braking, walking on a level surface at various speeds, sitting down/standing up, stepping off a curb or a stair, etc. While others have investigated various exercise, occupational, and sports activities (e.g., jumping jacks, box lifting, soccer heading, etc.), these are not ADLs for most individuals (although such references may be helpful in situations where the individual actually performed such activities). There have been several peer-reviewed publications that report the forces associated with ADLs[4-7], often based on experimental protocols where human subjects were fitted with accelerometers to measure the associated forces while the activity of interest was performed. It should be noted that most accelerometers employed in such studies measure the forces in units of g's. The reported ADL values are usually in the range of just over 1 g to 6 to 8 g's.

Experimental Design

A survey instrument was developed to probe individuals' understanding of g-values. Many questions employed a five-point Likert scale to respond to a specific question. Likert scales are employed to measure beliefs, opinions, attitudes, etc. of human subjects. The methodology typically consists of a statement followed by several possible responses (usually five) where the subject selects the response that is (in his/her judgement) most correct. The possible responses should be balanced in terms of equal numbers of positive and negative statements and one neutral statement. Here is an example:

I believe that I do not experience a force of 2 g's or higher in my normal daily activities.

__ Strongly disagree
__ Disagree
__ Neither agree nor disagree
__ Agree
__ Strongly agree

Several questions used an open response to the stated question. Here is an example: Please estimate how many g's would be associated with normal walking on a flat surface.

In general, survey questions probed the following:

- What force do we experience for various given activities such as walking?
- One's belief that forces of 2 g's or higher are not experienced by individuals in their daily normal activities.
- Self-evaluation of one's understanding of g's.
- Perception of other individuals' understanding of g's.
- Estimated g's to cause bodily injury.

In addition, demographic questions were included that sought to classify respondents according to:

- Age
- Gender
- Highest level of education
- If a college degree was completed, what was the major?
- Have you completed at least one year of college physics?
- Do you regularly read scientific magazines and/or watch scientific-based educational programs or documentaries?

The survey was administered using Qualtrics, a popular platform employed by researchers to develop, run, and analyze online surveys. Participants were provided the link and otherwise completed the survey anonymously. Participants were recruited from a university (students) and regional church, civic, and professional groups. A total of 610 persons participated. Basic demographic information is summarized in **Figure 1**. The male and female percentages were 44.4% and 55.6%, respectively.

In terms of those who completed a college degree (n = 279 — where n indicates the number of relevant responses), 8.2% earned an engineering degree; 14.3% a science degree; 28% a liberal arts degree; and 24% a business degree — with the remainder earning an arts, health sciences, social sciences, or other degree. For participants who completed some college or completed college (n = 511), 21.9 % completed at least one year of college physics and 78.1% did not. Just over 18% of all participants (n = 112 respondents) agreed/strongly agreed that they regularly read scientific magazines or journals and/or viewed scientific programming.

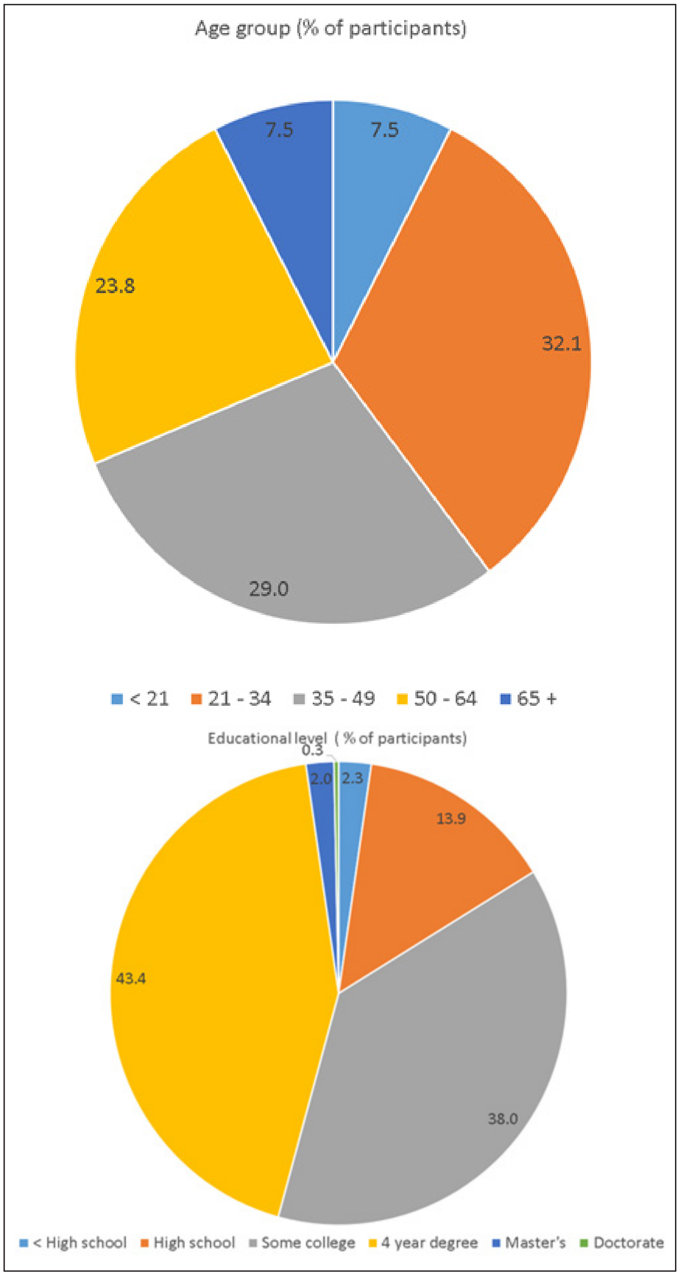

Figure 1
Age group of the study participants (top) and educational level (bottom). Total participants: 610.

Results

Participants were asked if they believed that they had never experienced 2 g's or higher in their normal daily activities. **Figure 2** presents the results for all 610 respondents (top) and a separate breakout (bottom) for those who attended some college and completed (or not) a one-year

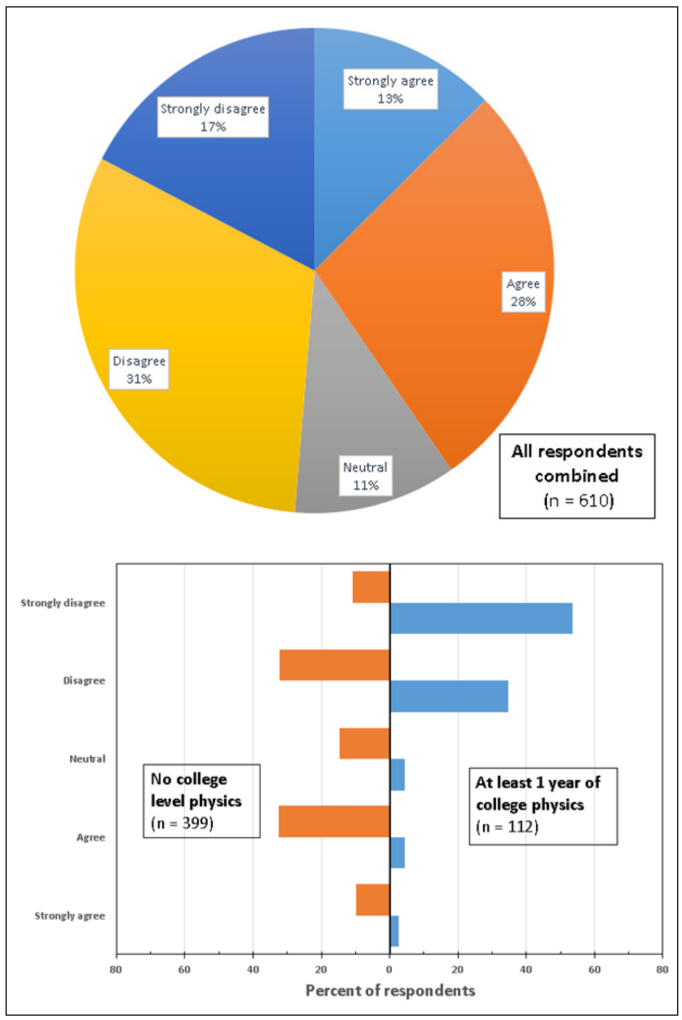

Figure 2
Participant responses to the question (top): "I believe that I do not experience 2 g's or higher in my normal daily activities." Responses for all participants and (bottom) broken out by completion of at least one year college physics class (right) or never completed a college-level physics class (left).

college physics class. A five-point Likert scale was used for these questions.

It is interesting to note that 41% (28% + 13%) of all respondents (n = 610) agreed or strongly agreed with the statement that one doesn't experience 2 g's or more in one's daily activities. Only 17% strongly disagreed that the statement was incorrect.

When one looks at participants who completed or at least attended some college, 45% (35% + 10%) of those who had no college physics class agreed or strongly agreed with the statement while only 7% (4% + 3%) of those who had completed a college physics class agreed or strongly agreed with the statement. Approximately 89% (35% + 54%) of the "completed physics" group disagreed or strongly disagreed with the statement as opposed to 40% (30% + 10%) of the "no physics class" group.

Figure 3 present the responses to the open-ended question: "How many g's are associated with normal walking on a flat surface?" — with the results for all 610 respondents (top) and a separate break-out (bottom) for those who attended some college and completed (or not) a one-year college physics class.

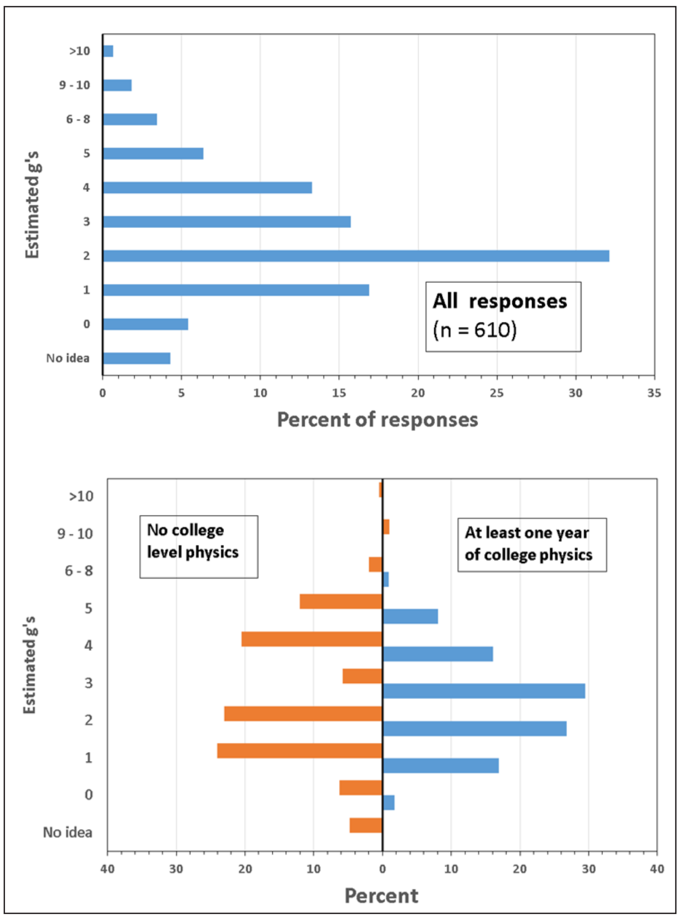

Figure 3
Responses to the question: "How many g's are associated with normal walking on a flat surface?" Responses for all participants combined (top) and broken out by completion of a one-year college physics class (bottom right) or at no college-level physics (bottom left).

Interestingly, for all responses combined, approximately 4% had no idea, and 5% thought the value for normal walking was 0 g's. For all responses, almost 17% estimated 1 g, and 32% estimated 2 g's. Furthermore, 11 respondents provided estimates of 9 to 10 g's, and four thought it was > 10 g's. When examined in terms of those who had completed a college physics class (or not), none of the "completed physics" respondents "had no idea," and just under 2% estimated 0 g's; for the "no physics class," 19 respondents "had no idea," and 25 respondents thought the value was 0 g's. Also, only one of the "completed physics" respondents thought the g's were 6 to 8 or higher whereas 14 of the "no physics class" respondents provided estimates of 6 to 8 g's or greater. For reference, the value for normal walking on a flat surface was measured for human subjects to be 1.45 to 2.07 g's in the lumbosacral region[7].

Figure 4 presents respondent estimates of how many g's it takes to cause a bodily injury.

For all 610 responses, a total of 32 participants (just over 5%) "had no idea" (only three of these were "completed physics" respondents). Fortunately, no one responded that 0 g's was a good estimate, indicating that all respondents felt that at least some force was required to cause a bodily injury. To cause a bodily injury, 14 respondents felt only 2 g's was required, 27 estimated 3 g's, 30

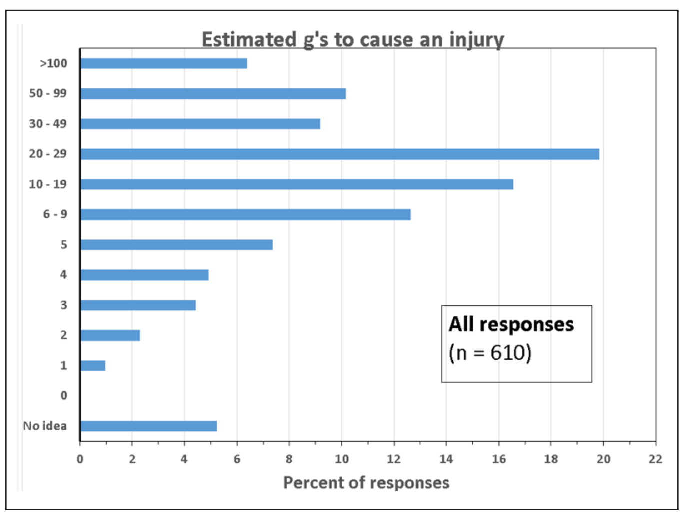

Figure 4
Respondent estimates of how many g's would be required to cause a bodily injury.

estimated 4 g's, and 45 indicated 5 g's. A total of almost 46% of all respondents thought the value was between 10 and 50 g's; 62 respondents felt the value was between 50 and 99 g's, and 39 felt it was greater than 100 g's. Of those who "completed physics," less than 8% felt the value was 5 g's or less whereas almost 22% of "no physics class" estimated the value to be < 5 g's. This question was intended to get a general feel for what respondents felt about how many g's were needed to cause a bodily injury; no specific injury or injury type was indicated in the question. Obviously, the estimate range is injury-specific and a function of age, gender, and other biomechanical and physiological parameters.

Figure 5 presents the results of two Likert scale questions: 1) "I think I have a good understanding of what 1 g, 2 g's, 3 g's, etc., means"; and 2) "I think most people have a good understanding of what 1 g, 2 g's, 3 g's, etc. means."

It is interesting to note that overall individuals tend to rank their personal level of understanding higher than their perception of other individuals' level of understanding. In general, very few participants (22) felt they "strongly agreed" with this statement; only 38 agreed with this statement. About 36% were neutral on the topic, and almost 54% of respondents disagreed or strongly disagreed. When asked to estimate the level of understanding for others, only two individuals "strongly agreed" and 17 "agreed"; individuals felt almost 60% of others had limited understanding of g's.

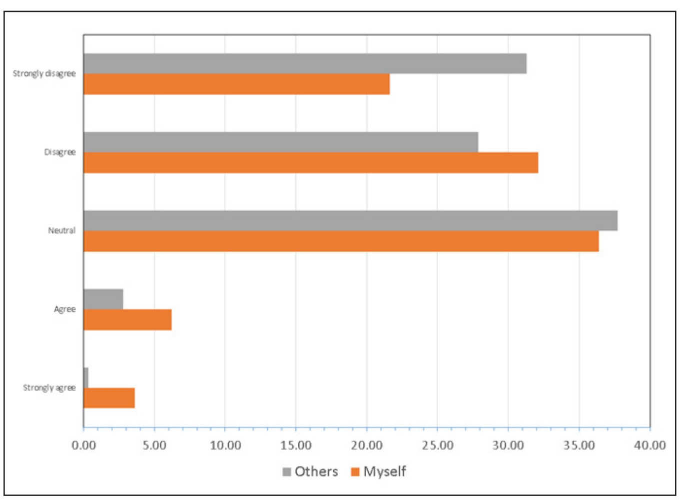

Figure 5
Responses (all 610 participants) to the question: "I think I have a good understanding of what 1 g, 2 g's, 3 g's, etc. means" (myself) and "I think most people have a good understanding of what 1 g, 2 g's, 3 g's, etc. means" (others).

There were no obvious influences of age group with two exceptions. Of the 46 respondents who were 65 years of age or older (7.5% of respondents), "I have no idea" responses were more common percent-wise versus the younger age groups. Also, almost all of the 65+ responders disagreed/strongly disagreed that they understood what 1 g, 2 g's, 3 g's, etc. means. Regarding gender, females were less likely to agree/strongly agree that they understood what 1 g, 2 g's, 3 g's, etc. means versus males. Of those who agreed/strongly agreed that they regularly read scientific magazines and/or watched science educational or documentary programs, there was a tendency for such individuals to agree/strongly agree that they understood what 1 g, 2 g's, 3 g's, etc. meant at a higher level versus those who did not read or watch science-based media. This was also true of engineering/science majors versus other college majors.

Discussion

Overall, the results indicate that most individuals have a limited understanding of what g's are all about. College-educated persons who completed a college-level course in physics tend to do better, but the "improvement" is not drastic. It is concerning that many individuals may believe that we don't experience much above 2-g activities in our daily lives and that some believe normal walking is associated with 0 g's. This is not necessarily surprising in that most individuals outside a few fields, such as specialized engineering/physics areas (mechanical engineering, aerospace, injury event reconstruction, biomechanics, and similar disciplines), don't deal with g's outside of what they see and hear in popular culture (which may not be very frequent).

For most individuals, this limited understanding of g's is probably not a major issue in their day-to-day lives. However, this can be a significant problem in the legal system when jurors are asked to weigh evidence that involves forces presented as g's. In a personal injury case, the defense attorney may say "only 3 to 4 g's were experienced by the claimant" (implying: therefore, no injury). The plaintiff attorney alternately states: "But my client experienced three to four times the force of gravity!" (therefore: injury). Obviously, this can be very confusing to jurors, especially without any understanding of what g-force values mean and what one experiences (or doesn't) in daily life.

A solution to this problem is for the expert(s) who cite forces in terms of g values to also reference various ADLs to provide a framework for jurors to understand the facts of the case and hopefully arrive at a rational decision. Any referenced ADLs should, in fact, be real activities of daily living as experienced by regular people doing "regular" activities and not necessarily include activities such as boxing punches, football helmet-to-helmet hits, etc. One possible exception may be in blunt head trauma cases. Another may involve individuals who are active in a specific activity or line of work. For example, it may be useful and relevant to cite the forces associated with lifting objects for a person who works on a loading dock — for that person, "lifting" is, in fact, an "activity of daily living."

It should be noted that some experts may cite certain ADLs as somehow modeling or representing a specific injury situation. For example, an expert may opine that falling backward into a chair somehow models a rear-end collision. ADLs are "normal" activities and not intended to model any injury situation. ADL forces and the involved time frames of such "voluntary" motions do not translate into "injury models." In general, it is a misuse and misapplication of ADLs to say that a specific injury did or did not occur (specific causation) just because the associated ADL g values are "low."

Summary and Conclusion

Referencing ADLs to provide an understandable reference of what g values are about is useful to jurors and others seeking to rationally understand what g-force values say and don't say. The results of this study indicate that most individuals have a limited (and often incorrect) understanding of g forces; referencing ADLs can minimize such problems.

The selected ADLs should be relevant to the case and not significantly exceed the levels of forces involved. Most of us walk from point A to point B, stand up, and sit down, experience vehicle braking, go up and down stairs, etc. Most of us understand what ADLs are in terms of personal experiences. Without such ADL references, jurors and others can be misled (sometimes purposefully) by statements from either side (defense and/or plaintiff) regarding a specific situation such as injury causation. Without such ADL references, the chances of analyzing a given situation (or weighing evidence) may be high in terms of reaching the wrong conclusion.

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