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A Comparison Of Direct And Indirect Assessments Of Standing Lumbar Lordosis In Asymptomatic Adults

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A COMPARISON OF DIRECT AND INDIRECT ASSESSMENTS OF STANDING LUMBAR LORDOSIS IN ASYMPTOMATIC ADULTS

by

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This thesis, submitted by Nolan Adam Larson in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

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This thesis is being submitted by the appointed advisory committee as having met all of the requirements of the School of Graduate Studies at the University of North Dakota and is hereby approved.

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Nolan Adam Larson

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Table

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ABSTRACT

Background: While lumbar lordosis is often indirectly (visually) assessed by practitioners to guide treatment, it is not clear how well direct and indirect assessments agree. The aims of this study were to (a) determine the intra- and inter-rater reliability of two indirect assessments (visual assessments of real and 3D body scanned people), and (b) determine the agreement between direct and indirect assessments (3D scan-extracted vs. visual assessments).

Methods: Fifty asymptomatic participants were physically landmarked and scanned with and without landmarks using the *Vitus Smart* 3D whole body scanner, after which 10 practitioners visually assessed the lumbar lordosis of each participant. One week later, practitioners visually assessed the scanned images of the 50 participants plus 15 duplicates, and two weeks later, practitioners and participants again presented with practitioners repeating their visual assessments. Lumbar lordosis was also directly assessed from scan-extracted data. Cohen's Kappa was used to determine the intra- and inter-rater reliability of indirect assessments, with polyserial correlation (p_s) used to determine the agreement between direct and indirect assessments.

Results: The intra- and inter-rater reliability of indirect assessments of real people was fair (κ [95%CI]: 0.37 [0.20, 0.54]) and slight (κ [95%CI]: 0.01 [−0.09, 0.11]), respectively. The intra- and inter-rater reliability of indirect assessments of scanned people was moderate (κ [95%CI]: 0.56 [0.45, 0.67]) and slight (κ [95%CI]: 0.13 [0.08, 0.19]), respectively. The agreement between direct and indirect assessment was moderate (p_s=−0.41, p=0.04).

Conclusion: Intra-rater reliability of indirect assessments of lumbar lordosis was fair to moderate, inter-rater reliability was slight, and the agreement between direct and indirect assessments was moderate. It appears that most of the error in indirect assessments is due to technical error, highlighting that efforts to improve reliability should focus on minimizing technical errors. 3D body scanning technology could be used as a training and teaching tool to improve measurement reliability.

CHAPTER 1

INTRODUCTION

Posture is defined as the relative arrangement of the parts of the body — the position from which human movement starts and ends (Kendall, McCreary, Provance, Rodgers, & Romani, 2005). Posture, both static and dynamic, is commonly assessed by practitioners (e.g., orthopedic surgeons, physical therapists, chiropractors, occupational therapists, exercise professionals) to guide treatment (e.g., by providing a baseline assessment of movement quality and/or musculoskeletal dysfunction).

In the United States, back pain affects over 100 million individuals and costs more than $200 billion per year due to job absenteeism, medical and legal fees, disability payments, worker's compensation, and long-term disability insurance (Ma, Chan, & Carruthers, 2014). Lumbar spine posture is considered an indicator of low back pain. Individuals with a restricted ability to readily change from faulty lumbar spine posture tend to experience increased spinal stress (Kendall et al., 2005, p. 52). Therefore, the ability to accurately and reliably assess lumbar spine posture is important for back health and potentially physical performance.

Lumbar lordosis, the degree of anterior curvature of the lumbar spine, is a commonly used measure of lumbar spine posture (Tomkinson & Shaw, 2008). Indirect (visual) assessments of lumbar lordosis are widely used because they are quick, cheap, easy, and require little to no equipment. Unfortunately, indirect assessments demonstrate slight to fair reliability (Fedorak, Ashworth, Marshall, & Paull, 2003). In recent decades there has been a proliferation of direct postural assessment tools, from rulers, inclinometers, and goniometers through to digitized photographic and radiographic techniques. Unfortunately, while direct assessment tools have become increasingly sophisticated over time, measurement accuracy and reliability has not always been reported or concurrently improved (Tomkinson & Shaw, 2013). A promising tool that has recently been used for postural assessment is three-dimensional (3D) whole body scanning, which to date, has primarily been used for textiles, clothing, ergonomics (human factors), engineering, manufacturing, and computer generated imagery (CGI) applications (Daanen & Ter Haar, 2013). 3D scanners use multiple video camera angles or project white light or non-ionizing laser light, infrared waves, or millimeter waves onto the body, and use a series of cameras to capture the reflection as Cartesian coordinates. 3D scanners offer a number of advantages to postural assessment, including the capture of the surface image of a human body in a time-efficient (<15 s) and non-invasive manner, and the ability to directly and indirectly assess, which can be reassessed at any time without the individual being present.

Reliability has important decision-making implications when assessing individuals, as it is used to determine the likely range for a single measurement, the likely range of a change in a measurement in response to an intervention, and for sample size estimation in research design (Hopkins, 2000). While the reliability of direct (body scan) assessment of lumbar lordosis (Tomkinson & Shaw, 2013) and indirect (visual) assessment of photographs of lumbar lordosis (Fedorak et al., 2003) has been reported, it is not known how well direct and indirect assessments agree. Scan images have the potential to complement visual assessments by allowing for the creation of a data repository that can be analysed on spec, offering on-going learning opportunities for students and practitioners. It is also not known how best to go about improving the precision of postural measurement. For example, while Tomkinson and Shaw (2013) estimated that most (78%) of the error associated with body scan assessments of lumbar lordosis was due to postural error (i.e., within-subject error), similar data are lacking for indirect assessments. Therefore, using assessments of standing lumbar lordosis in asymptomatic adults, this study aimed to (a) determine the intra- and inter-rater reliability of two indirect assessments (visual assessments of real and body scanned people), and (b) determine the agreement between direct and indirect assessments (scan-extracted vs. visual assessments).

CHAPTER 2

METHODS

Participants and sampling

Practitioners (*n*=10) and participants (*n*=50; female, *n*=18; male, *n*=32) were recruited by convenience. The practitioners were registered physical therapists (mean±SD: age, 38±11 years; clinical experience, 16±12 years) who (a) were registered and practicing musculoskeletal or rehabilitative physical therapists, and (b) had least two years of full-time (or equivalent part-time) clinical experience. The participants were university students (mean±SD: age, 27±12 years; height, 174±11 cm; mass, 72±14 kg) who (a) were able to stand unsupported in the dark for 15 s on a raised platform, (b) presented asymptomatic for low back pain, and (c) did not present with injuries preventing the accurate location of bony landmarks (i.e., spinous processes of the thoracic, lumbar and sacral spine). The Human Research Ethics Committee of the University of South Australia and the Institutional Review Board of the University of North Dakota approved this study.

Procedures

Upon arrival, participants completed a short demographic questionnaire where they self-reported their age, gender, occupation and physical activity levels, and then had their height (cm) measured with a stadiometer and mass (kg) measured with a digital weighing scale. Following completion of the questionnaire, participants changed into form fitting underwear (briefs for men and briefs and sports bra for women) behind a medical screen, and then had the spinous processes of the 12th thoracic vertebra (T12), 3rd lumbar vertebra (L3), and 2nd sacral vertebra (S2) landmarked by a registered practitioner using the procedures described by

Tomkinson and Shaw (2008). Spinal landmarks were identified by small triangular pieces of balsa wood that were placed on the skin (adhered by double-sided tape) pointing inferiorly to the landmark. These raised landmarkers were used as the *Vitus Smart* 3D whole-body scanner (Human Solutions GmbH, Kaiserslautern, Germany) did not show color or texture. Participants were then scanned in their “normal” standing posture using the procedures described in detail by Schranz, Tomkinson, Olds, and Daniell (2010). Briefly, upon entering the scanner, participants took several steps in place to assume their normal standing posture and then stood still for the 15-second duration of scan. Participants were then re-scanned without the three raised landmarkers.

Lumbar lordosis was directly measured post-survey from the body scans using the detailed procedures of Tomkinson and Shaw (2008). Briefly, *DigiSize v2.3* (Cyberware, Monterey, CA, USA) software was used to identify the Cartesian coordinates corresponding to the three spinous processes, with Cartesian coordinate geometry and trigonometry used to calculate lumbar lordosis. Lumbar lordosis was measured in angular degrees (°) as the included angle formed between the intersection of a line joining the T12 spinous process to the peak of the lumbar spinal curve, and a line joining the peak of the lumbar spinal curve to the S2 spinal process. A smaller angle indicated a greater anterior curvature of the lumbar spine. The time burden per participant was ~20 min per testing session and the body scan data extraction process took ~5 min per scan.

Following the scan, practitioners entered, one at a time, and indirectly assessed the lumbar lordosis of each participant. Lumbar lordosis was graded as the degree of anterior curvature of the lumbar spine relative to ‘normal’ posture, along a spectrum of deviations from normal, mild, moderate to severe. While lumbar lordosis was defined and operationalized (see previous paragraph) to the practitioners, neither normal posture nor the three deviations were. Practitioners were allowed to observe the participants from any angle and palpate landmarks if desired, but they were not allowed to ask participants any questions or ask them to move from normal standing. This process was repeated approximately two weeks later, with the presentation order of participants randomized. The time burden per practitioner and per participant was ~30 min per testing session.

Approximately one week later, practitioners received a randomized set of rotating movie files (.avi files) of all 50 scanned participants, plus 15 randomly selected duplicate scans to estimate the reliability of indirect assessments of body scanned people. Practitioners were asked to indirectly assess the lumbar lordosis of the scanned participants using the same grading criteria as described above. They were also informed that a number of duplicates had been included and that they needed to assess each scan independently. The time burden per practitioner was ~90 min.

Statistical analyses

The indirect assessment data are ordinal and the direct assessment data are interval. Intra-rater (the same practitioner rating the same participant on two separate occasions) and inter-rater (different practitioners rating the same participant) reliability of the indirect assessments were assessed by Cohen’s Kappa using the four deviation grades (normal, mild, moderate, and severe). Kappa coefficients were qualitatively interpreted using the scale of magnitudes recommended by Landis and Koch (1977). Values <0.00 indicated poor agreement; 0.00 to 0.20, slight agreement; 0.21 to 0.40, fair agreement; 0.41 to 0.60, moderate agreement; 0.61 to 0.80, substantial agreement; and 0.81 to 1.00, almost perfect agreement (Landis & Koch, 1977). Intra- and inter-rater reliability were also examined visually by generating frequency distributions of absolute intra- and inter-rater differences.

The agreement between direct and indirect assessments was assessed by polyserial correlation (p_s). The probability value associated with the polyserial correlation coefficient was calculated using Spearman's equivalent (Drasgow, 1988). A chi-square test was used to test the assumption of bivariate normality required by the polyserial coefficient (if $p>0.05$, then the assumption is not rejected, i.e., the best-fitting function is linear). Polyserial correlations were qualitatively interpreted using the scale of magnitudes recommended by Cohen (1988), where correlations of 0.1, 0.3, and 0.5 were used as thresholds for weak, moderate, and strong, respectively.

CHAPTER 3

RESULTS

Intra- and inter-rater reliability of different indirect assessments

The intra- and inter-rater reliability of indirect assessments of real people was fair (κ [95%CI]: 0.37 [0.20, 0.54]) and slight (κ [95%CI]: 0.01 [−0.09, 0.11]), respectively. The intra- and inter-rater reliability of indirect assessments of scanned people was moderate (κ [95%CI]: 0.56 [0.45, 0.67]) and slight (κ [95%CI]: 0.13 [0.08, 0.19]), respectively.

The most frequent intra-rater difference for indirect assessments of real and scanned people was zero (i.e., the same visual rating was assigned by the same practitioner for test and retest), with 93% to 95% of all intra-rater differences within one point (Table 1). The most frequent inter-rater difference was one (i.e., a 1-point rating difference between the test measures of two practitioners), with 83% to 85% of all inter-rater differences within one point (Table 1).

Table 1. Frequency distribution of intra- and inter-rater differences in indirect assessments of lumbar lordosis in asymptomatic adults. Intra- and inter-rater differences are expressed as absolute rating-point differences, with frequencies represented as percentages.

	|point difference|	**real vs. real**	**scan vs. scan**
Intra-rater	3		1
	2	5	6
	1	39	23
	0	56	70
Inter-rater	3	1	3
	2	14	14
	1	53	43
	0	32	40

Agreement between direct and indirect assessments

The agreement between direct (scan-extracted) and indirect (visual) assessment of lumbar lordosis was moderate (p_s=−0.41, p=0.04), with the best-fitting function linear (χ^2=21.8, p=0.06). Consistent with expectation, the direction of the correlation was negative, meaning that smaller directly measured spinal angles (indicating greater anterior curvature of the lumbar spine or increased lordosis) were visually assessed as more deviant (Figure 1).

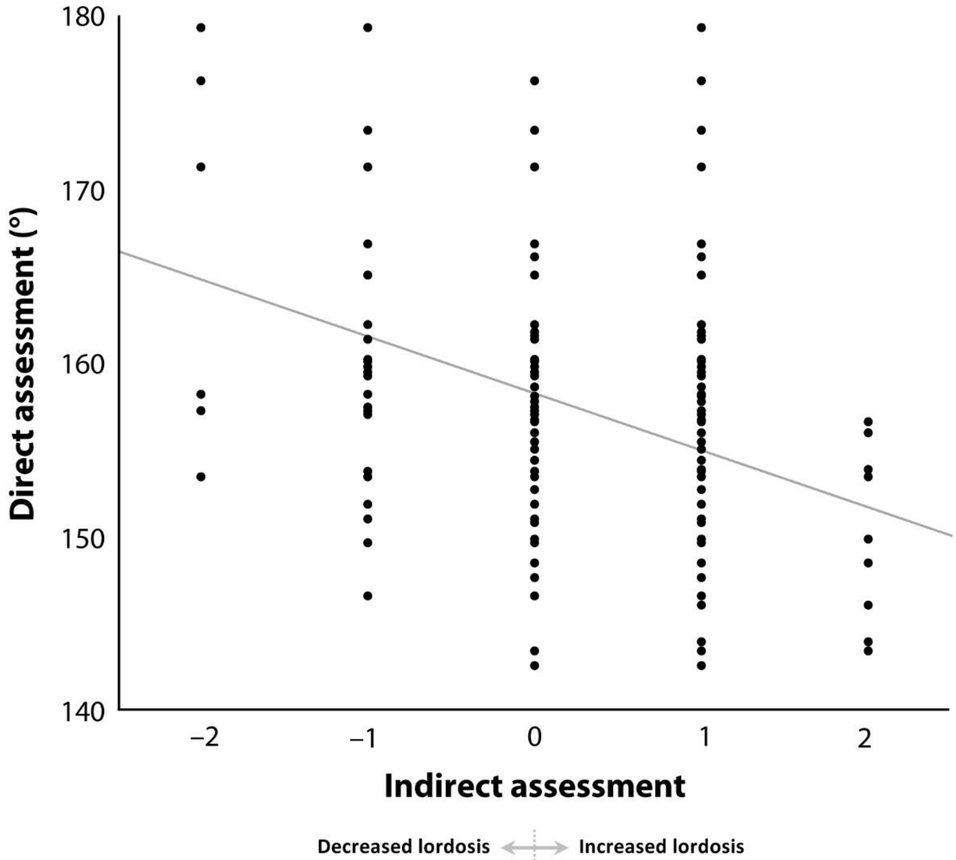

Figure 1. The relationship between direct (scan-extracted) and indirect (visual) assessments of lumbar lordosis. All assessments were made on 50 asymptomatic adults, with direct assessments made using Cartesian coordinate geometry and trigonometry and indirect assessments made by 10 accredited physical therapists. For direct assessments, smaller angles indicated increased lordosis and larger angles indicated decreased lordosis. For indirect assessments, positive values indicated increased lordosis and negative values indicated decreased lordosis. The regression line is shown as a thin solid grey line.

CHAPTER 4

DISCUSSION

This is the first study to examine the intra- and inter-rater reliability of indirect (visual) assessments of the lumbar lordosis of real people, and that of 3D body scanned people, as well as the agreement between direct (3D scan) and indirect assessments. It found that the intra-rater reliability of indirect assessments of lumbar lordosis was fair to moderate, whereas inter-rater reliability was slight and no better than chance alone in the case of the inter-rater reliability of real people. The agreement between direct and indirect assessment was moderate.

Implications

These findings have several important implications for practitioners and researchers as indirect assessments of real people are regularly used to guide diagnosis and treatment. Given this study found that the intra-rater reliability of visual assessments of lumbar lordosis are (at best) moderate, it is important that measurement reliability be improved. This may be achieved by reducing postural error (i.e., the within-subject error) and/or technical error (i.e., the error in the visual assessment process) (Tomkinson & Shaw, 2013). Postural error could be affected by growth, physical activity or diurnal variability, whereas technical error could be affected by differences in landmark location, assessment technique, rating criteria or equipment. Postural error may benefit from selecting appropriate test-retest measurement intervals and by minimizing diurnal variability (e.g., by testing and retesting people at the same time of day and on the same day of the week). Technical error may benefit from strict adherence to explicit assessment protocols and thorough tester training.

The results of this study can be used to estimate the magnitude of postural and technical error. Assuming that the postural and technical errors were independent and normally distributed, then the total error can be estimated as the unexplained error in repeated visual assessments of real people (i.e., 1 minus the intra-rater kappa coefficient for real people, $\therefore 1 - 0.37^2 = 0.86$ or 86%) and technical error as the unexplained error in repeated visual assessments of scanned people (i.e., 1 minus the intra-rater kappa coefficient for scanned people, $\therefore 1 - 0.56^2 = 0.69$ or 69%). Postural error (i.e., the within-subject error free from technical error) can therefore be estimated as the difference between the total and technical errors ($\therefore 0.86 - 0.69 = 0.17$ or 17%). These estimates suggest that about 80% of the total intra-rater error in visual assessments of lumbar lordosis can be ascribed to technical error, and that efforts to improve precision should focus on reducing technical error. (Note, using the same approach, practically all of the inter-rater error can be ascribed to technical error).

This study also found that (a) the agreement between direct and indirect assessments of lumbar lordosis was moderate, and (b) the expected direction of the relationship was observed, with directly measured angles indicating that increased lordosis was visually assessed as more deviant. Interestingly, the best fitting function was linear, which indicates that the difference between rating scores was uniform. Figure 1 shows there was a fair degree of scatter about the regression line, confirming the moderate correlation. Further examination shows that normal ratings ranged from 143° to 176° (mean±SD: 158±7°) and that lumbar angles between 143° and 176° were rated between moderately decreased and moderately increased.

While 3D whole body scanners are large, somewhat expensive (depending on the type of scanner), require skilled operation and do not reflect true clinical practice, they do offer several advantages to postural assessment (Tomkinson & Shaw, 2013). First, they quickly and non-invasively capture a complete image of an individual that can be reassessed in the future without the individual being present. Second, images of scanned people can be pooled to create a virtual database to familiarize practitioners with common and extreme postures that can be visualized in 3D, and to compare direct and indirect postural assessments made by the same practitioner or by different practitioners. Third, because there is a lack of current normative data available, 3D scanners could also be used to establish population-representative normative data that could be combined with visual assessments to assist with the operationalization of visual rating criteria (e.g., normal, mild, moderate and severe).

Comparisons with other studies

To date, only one other study has estimated the intra- and inter-rater reliability of visual assessments of lumbar lordosis. Using a sample of 28 chiropractors, physical therapists, physiatrists, rheumatologists, and orthopedic surgeons who assessed the cervical and lumbar lordosis of photographed participants (with and without back pain), Fedorak et al. (2003) reported the collective intra-rater reliability as fair (κ [(95% CI]: 0.50 [0.02, 0.98]) and the inter-rater reliability as slight (κ [(95% CI]: 0.16 [0.00, 0.48]). Orthopedic surgeons demonstrated the best intra-rater reliability (κ [(95% CI]: 0.77 [0.27, 1.00], substantial) and physical therapists the best inter-rater reliability (κ [(95% CI]: 0.29 [0.00, 0.46], fair). The intra-rater reliability for physical therapists was moderate (κ [(95% CI]: 0.49 [0.09, 0.89]). These intra-rater reliability statistics reported by Fedorak et al. (2003) are similar to those reported for scanned people in this study, although their inter-rater reliability estimates are somewhat better. It is important to remember however that these reliability estimates, like those for scanned people in this study, reflect only the technical error associated with the visual assessment process. Interestingly, Tomkinson and Shaw (2013) estimated that the technical errors associated with 3D body scan postural assessments were negligible, with most of the error attributed to postural error. Unfortunately, no data are available with which to compare the correlations between direct (3D scan) and indirect (visual) assessments.

Strengths and limitations

This is the first study to examine the intra- and inter-rater reliability of two indirect assessments of lumbar lordosis. While only the visual assessment of real people reflects true clinical practice, the quantification of the reliability of both real and scanned people allowed for the estimation of both postural and technical errors. It is also the first study to compare direct (3D scan) and indirect (visual) assessments of lumbar lordosis, which could be used to establish objective grading criteria and to assign grades to directly measured angles.

While this study used a large participant pool (*n*=50) that resulted in reasonable precision for the estimates of reliability (Hopkins, 2000), the convenience sampling strategy probably resulted in a sample unrepresentative of that typically observed by physical therapists. The recruitment of only asymptomatic adults resulted in a homogenous sample (e.g., no participants were rated as severely deviant), which probably reduced the reliability and correlation estimates. The small number (*n*=10) and homogenous group of practitioners (who were all trained at a single institution) may not have been representative of all physical therapists, and it is unclear whether our results could be applied to other groups of practitioner (e.g., other allied health professionals). A more heterogeneous group of practitioners would likely have resulted in smaller reliability estimates. Finally, while lumbar lordosis was defined and operationalized, the grading criteria were not, and it is possible that the interpretation of grading criteria differed between practitioners. Nonetheless, this study was more concerned with the reliability of current clinical judgment rather than the reliability of practitioners' ability to follow a set protocol.

Conclusion

This study indicated that the intra-rater reliability of indirect assessments of lumbar lordosis was fair to moderate, the inter-rater reliability was slight, and the agreement between direct and indirect assessments was moderate. These results have important decision-making implications for practitioners and researchers when assessing single and change measurements in individuals. Our results indicate that visual assessment alone is not recommended for lumbar lordosis, especially not for comparisons between practitioners. In order to improve measurement reliability, it is recommended that clinicians and researchers concentrate on reducing technical error by strictly adhering to assessment protocols and undergoing extensive tester training. 3D body scanning technology offers promise in this regard through the creation of a virtual database of scanned bodies, which can be used as a teaching and training tool requiring minimal participant burden. Future research should (a) include both asymptomatic and symptomatic people (to examine posture with respect to pain or potential pain and loss of function), (b) examine the reliability of indirect measures and compare both direct and indirect measures across other body postures, and (c) examine the factors that cause practitioners to disagree in the hope of developing standardized guidelines for visual assessment.

APPENDICES

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October 31, 2017

Principal Investigator(s):	Nolan Larson
Project Title:	A Comparison of Visual Assessment Methods of Standing Lumbar Lordosis in Asymptomatic Adults
IRB Project Number:	IRB-201710-097
Project Review Level:	Exempt 4
Date of IRB Approval:	10/31/2017
Expiration Date of This Approval:	10/30/2020

The application form and all included documentation for the above-referenced project have been reviewed and approved via the procedures of the University of North Dakota Institutional Review Board.

If you need to make changes to your research, you must submit a Protocol Change Request Form to the IRB for approval. No changes to approved research may take place without prior IRB approval.

This project has been approved for 3 years, as permitted by UND IRB policies for exempt research. You have approval for this project through the above-listed expiration date. When this research is completed, please submit a Termination Form to the IRB.

The forms to assist you in filing your project termination, adverse event/unanticipated problem, protocol change, etc. may be accessed on the IRB website: http://und.edu/research/resources/human-subjects/

Sincerely,

Michelle L. Bowles

Michelle L. Bowles, M.P.A., CIP
IRB Coordinator

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Cc: Grant Tomkinson, Ph.D.

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