CPRC CCRP

CANADIAN POLICE RESEARCH CENTRE

CENTRE CANADIEN DE RECHERCHES POLICIÈRES

TR-09-2001
Hangings - A Practical Study of Ligatures and Suspension Point Morphology

Tara Nicholls, B.Sc

TECHNICAL REPORT
September, 2000

Submitted by:
Ontario Provincial Police
Technical Identification Services Unit
Barrie, Ontario

NOTE: Further information about this report can be obtained by calling the CPRC information number (613) 998-6343

NOTA: Pour de plus ample renseignements veuillez communiquer avec le CCRP au (613) 998-6343

Executive Summary

The purpose of the study was to examine the physical evidence consistent with a self-inflicted hanging act, such as a suicide or auto-erotic death and provide a comparison through the examination of homicidal hangings. The goal of the study is to improve, through education, the investigative techniques at death scenes involving hangings and, ultimately, to be able to distinguish homicidal hanging scenes from suicidal scenes using physical evidence and a thorough investigation.

This study produced a large number of observations and measurements and these, combined with results of a survey of hanging cases and a literature review, led to the creation of a data form providing criteria for investigators in the area of suspicious hanging deaths.

Sommaire

Cette étude examine les éléments de preuve matériels d'une pendaison auto-infligée (suicide, mort auto-érotique), puis les compare à ceux d'un homicide par pendaison. Elle vise à améliorer, par l'éducation, les techniques d'enquête utilisées sur les lieux de décès par pendaison et à aider à distinguer les homicides par pendaison des suicides grâce à l'examen d'éléments de preuve matériels et à une enquête minutieuse.

On a formulé un grand nombre d'observations et on a élaboré quantité de mesures qui, conjuguées aux résultats d'une recherche sur des cas de pendaison et une recension des écrits, ont permis d'établir des critères relatifs aux morts par pendaison suspectes à l'intention des enquêteurs.

HANGINGS - A PRACTICAL STUDY OF LIGATURES AND SUSPENSION POINT MORPHOLOGY - PHASE II

By Tara Nicholls, B.Sc.

Canadian Police Research Council

Ontario Provincial Police Technical Identification Services Unit, Barrie, Ontario

Supervised by Staff Sergeant J. P. Downey

Completion Date: September 11, 2000

TABLE OF CONTENTS

LIST OF DIAGRAMS – APPENDIX A

LIST OF PHOTOGRAPHS -APPENDIX B

PAGE

LIST OF TABLES -APPENDIX C

*after subtraction of Initial Control Measurements
**prior to subtraction of Initial Control Measurements

LIST OF CHARTS -APPENDIX D

PAGE

PAGE

Abstract

The purpose of this study was to examine the physical evidence consistent with a self-inflicted hanging act, such as a suicide or autoerotic death, and provide a comparison through the examination of homicidal type hangings. The goal of the study is to improve, through education, the investigative technique at death scenes involving hangings and ultimately be able to distinguish homicidal hanging scenes from suicidal scenes, using physical evidence and a thorough investigation, should a questionable or indistinguishable scene arise.

Using the gallows constructed in the garage of the OPP Technical Identification Services Unit, in Barrie for Phase I of the study, modifications were made to accommodate the homicidal type hanging trials. This was accomplished by adding another winch to facilitate a drag or haul-up type of trials comparable to a homicidal act of hanging or post-mortem suspension made to look like a suicide. To accurately portray the weight of human, a simulation crash test dummy weighing 70.27 kg (154.6 lbs) was constructed using a burlap army bag filled with sand and dirt, and held together with 1" link chains. This "dummy" was repeatedly hanged (static fall trials) in trials using a ligature of common three-strand twist 3/8" polypropylene rope. The dummy was hanged 0.5 m, in fifteen trials along the length of one 4' x 8' kiln-treated spruce board. Then the dummy was dragged (drag trials) up 0.5 m, in fifteen trials alongside the hanging trials on the same board, using the winch, to simulate a homicidal hanging.

After each trial tapings were taken on the ligature side, using fingerprint lifting tape, to remove any particulate matter adhering to the surrounding drag or static fall indentation areas. The depths of the indentations made in the spruce board suspension beam at both the "ligature side" and "opposite side" were recorded. The tapings were scanned into a computer and the area and perimeter of each trial were calculated using Autosketch software Macroscopic

observations of the indentations and ropes used were made, and a macro and microscopic photographic analysis was completed for demonstration purposes. A survey of hanging cases using the OPP files available from Central Region, Barrie TISU was completed for two years, 1998 and 1999, to assess what is being recorded at hanging scenes, and demonstrate areas that require greater focus at a suspicious hanging death.

Observational results from this comparative study of suicidal and homicidal hangings indicate that at the macroscopic level, the amount of densification of the wood, in a cross-section of the indentation, is much greater in the static fall trials than the drag trials. In static falls the wood fibres were directed downward on both sides of the suspension beam, while in drags the fibres were directed up on the ligature side and down on the opposite side. Analysis of the indentations created in the wood suspension beams found that significantly deeper indentations were created in the static fall trials, than in the drag trials, due to the force that is created by the weight of the dummy. The area and perimeter calculations of the tapings revealed that generally the static fall indentations were much larger on the ligature side. In addition, the rope compression and filamentation was greater in the static falls, and directionality was observed in the drag trials due to snags in the rope pulled over the suspension beam.

Therefore, this combination of observations and measurements, combined with the results of the OMPPAC survey and literature review, resulted in the creation of a data form which provides criteria for education of new investigators in the area of suspicious hanging deaths.

Introduction

Hanging is defined as a mode of death in which a ligature is placed around the neck and tightened by the weight of the body (Fisher, 1993: 462). Hanging is distinct from strangulation, in that hanging involves the use of attaching the ligature to a suspension point, which is an external fixed object, and gravity is the main constriction force that acts upon the body (Hucker and Blanchard, 1992: 5 11 ;Jaffe, 1999: 148; Davison and Marshall, 1986: 23).

Hangings may be classified into five general types – judicial, suicidal, autoerotic, accidental or homicidal. For a complete review of these types refer to Phase I of this report (Nicholls, 2000). The focus of this introduction is almost exclusively a review of death scene characteristics related to homicidal type hangings. To briefly review, suicidal hangings are self-inflicted and constitute the majority of hangings found (Davison and Marshall, 1986: 23), while homicidal hangings are the rarest type (Simon, 1998: 1 1 19; Püschel et al., 1984: 141; Leth and Vesterby, 1997: 65; Lew, 1988: 285; Vieira et al., 1988: 289; Davison and Marshall, 1986: 23; Fisher 1993: 464; Cooke et al., 1988: 277). Homicidal hangings are characterized by two categories – hanging as a method of homicide (hereafter called true homicidal hanging), and the post-mortem suspension of an individual to imitate a suicide, thereby covering up a murder (Püschel et al., 1984: 141; Leth and Vesterby, 1997: 65).

A careful analysis of the crime scene involving a suspicious hanging death is required to distinguish elements characteristic to homicidal hangings. Mueller (1932: 175-176) states that knowledge of the detailed circumstances surrounding the death and the crime scene are at least as important as the autopsy findings. Therefore, a thorough investigation, combined with the results of a thorough autopsy, should yield evidence that distinguishes homicidal hangings from suicidal hangings.

Positive death scene findings characteristic of a homicidal hanging scene include signs of a fight or struggle (Püschel et al., 1984: 147), indicated by a disturbance of the furniture, for example (Vieira et al., 1988: 288). In one case, bloodstains and broken objects within the house raised the suspicion of investigators, as the victim was found hanging from a beam at the front door of the stable (Radian and Radovici, 1957: 232). Similarly, torn and bloodstained clothing on the victim of a post-mortem suspension made to appear as a suicide, correlated well with the findings at autopsy of blunt force trauma preceding strangulation (Boltz, 1956: 133-134). While such signs of a struggle should be obvious, it must be noted however, that in suicidal hangings injuries can be found that are not related to crime. "Occlusion of the airway invariably elicits a struggle, a dramatic condition commonly referred to as air hunger" (author's emphasis) (Spitz and Fisher, 1980: 321). Injuries and signs of a struggle or violence may therefore be produced as a result of the body hitting an object during spasm, or by previous suicide attempts (Leth and Vesterby, 1997: 68; Fisher, 1993: 463; Vieira et al., 1988: 288).

Drag marks on the ground, and subsequent marks on the skin or clothing of the victim are also indications of a struggle (Püschel et al., 1984: 147). In one case described by Rooks (1935: 106-107) smears of cattle muck on the hands and face of a hanged woman in a cattle shed were caused by strangulation on the ground by her son. In another case described by Kipper (1926: 219-220), discovery of the fight scene and the trail of disturbed vegetation led searchers to the victim who had been dragged 20 metres by two men and subsequently hanged from a tree branch. Dirt on the victim that is not present at the scene should be noted (Fisher, 1993: 465), as well as materials, such as dust, that should be disturbed by the action of the victim but are found undisturbed at the scene (Püschel et al., 1984: 147).

The lack of stepping aids or elevated jumping-off points in close proximity, when the body is hanging free or completely suspended, is another characteristic of homicidal hangings (Fisher, 1993: 464; Püschel et al., 1984: 148). It is noted in the literature however, that in a homicidal hanging scene made to appear as a suicide, the criminals placed a stepping aid next to the victim (Radian and Radovici, 1957: 232). Therefore, the value of measurements taken at the hanging scene is extremely important. In a scene described by Rooks, (1935: 106) the victim was hanged from a ladder rung at such a height, and with such a short length of ligature, that there was no possible way she could have climbed around from the front of the ladder to the back and hanged herself. Careful measurements, combined with autopsy results, allowed investigators to reconstruct the scene, resulting in a confession of murder (Rooks, 1935: 108).

The type of knot used in the ligature must also be examined, to determine if the victim could have manufactured it (Püschel et al., 1984: 148). Mueller states that a complicated knot that is "not compatible with the personality of the deceased" points to a homicidal hanging (1932: 176). Similarly, a professional knot characteristic of a particular trade may aid in the identification of the deceased, if they are unidentified at a suicidal hanging (Mueller, 1932: 176). Mueller (1932: 175) advocates for the importance the knot, as "nearly all of the different craft professions use characteristic knot procedures" and advises removing the point of suspension, without untying the ligature, and keeping this with the body, for later examination. Fisher (1993: 465) states that "in suicide by hanging, right-handed persons usually place the knot of the noose on the right-hand side of the neck; left-handed persons place it on the left. Reversal of these positions is suspicious".

Materials such as hair or clothing caught inside the noose or knot are rarely seen in a suicide (Püschel et al., 1984: 148). In the case of the post-mortem suspension of the woman in her closet, a slip-knot was used that contained clumps of the victim's hair, an indication that this was not a suicidal hanging (Simon, 1998: 1120). Similarly, a hair bundle was found in the ligature of a post-mortem suspension of a woman., by her husband, from a door handle (Weimann, 1929: 139). Other cases have found a shirt collar (Boltz, 1956: 133), and head coverings (Rooks, 1935: 106; Klauer, 1933: 376) caught under the ligature around the neck. Therefore, careful analysis of the ligature and knots used can yield important information that death may have been a homicide.

Homicidal hangings are also suspected when the victim is tied up, however it is possible to find a bound victim in a suicide (Püschel et al., 1984: 148-149; Leth and Vesterby, 1997: 69), and often a reconstruction is required to determine if the victim could have hung themselves in that position.

Determining if the suspension of the hanging victim occurred before or after death, is another important factor in differentiating a homicidal hanging from a suicidal hanging (Leth and Vesterby, 1997: 68; Vieira et al., 1988: 288). Lividity in hanging cases is present in the feet, legs, and hands (Fisher, 1993: 465). The distribution of lividity at the scene should correspond to the hanging position, or it may indicate the post-mortem suspension of an individual (Jaffe, 1999: 148). Similarly, the position of the limbs after the onset of rigor mortis should correspond to the body's hanging position (Fisher, 1993: 465). Other pathological evidence, as reviewed in Phase I, (Nicholls, 2000) also provides an indication of whether the individual was alive at the time of suspension.

Examination of the suspension point and the ligature at the scene will provide further evidence of the type of death that has taken place (Püschel et al., 1984: 148-149). According to Popp, "the point of suspension has received too little attention, as far as the literature indicates"

(1931: 79). While this was written in the 1931 its relevancy has changed little for today's hanging cases. Grooves, rubbed off paint or rust, and polishing traces at the point of suspension are the result of using the ligatures to pull up the body over a wooden beam, door, tree limb, or metallic object (Püschel et al., 1984: 148). The wood fibres on the suspension beam in contact with the rope will bend in the direction of pulling (Püschel et al., 1984: 148). More specifically, Goddefroy (1923: 226) states "it is noticeable that the wood fibres, which came into contact with the sliding cord, are bent in the direction of the pull and thus will be pointing upwards on one side of the bar, and downwards on the other side of the bar". Popp (1931: 79-81) in his support of Goddefroy, outlines two cases in which examination of the suspension point and the directionality of the wood fibres resulted in two murder convictions. In both of these cases, a reconstruction of the hanging was conducted, to determine the weight required on the rope to produce a particular depth of indentation or gutter by removing the tree bark, on the tree limb (Popp, 1931: 80). Similarly, Klauer (1933: 377-380) describes two cases in which a reconstruction of the ligature around the suspension beam to correlate to the dust marks and drag marks created in the wood fibres, found it was not possible that these victims had hanged themselves. These reconstructions on the original suspension point conducted in suspicious hanging cases yielded very useful information about the circumstances surrounding the victim's deaths.

In addition to the suspension point showing directionality of fibres, the corresponding area of the ligature will also show evidence of having been pulled over the suspension beam. The direction of rope fibres will be opposite to the direction of pulling (Püschel et al., 1984: 148; Fisher, 1993: 464; Goddefroy, 1923: 226). In a case described by Klauer (1933: 376) the ligature used to pull up a victim was found to be somewhat polished in appearance and flatly pressed at the areas in contact with the suspension point, the top of the bedroom door frame. In addition, the fibres are likely to pick up some transfer material from the suspension point. Mueller (1932: 177) describes a case in which the ligature was soiled with rust from the steel-pipe over which the rope was drawn to hang the victim. This type of characterization is important if the individual was moved or cut down after hanging, and the original suspension point needs to be located or identified.

Thus, homicidal hanging death scenes often have very characteristic features that allow for a confident determination of the circumstances surrounding death. To identify these features, however, investigators should thoroughly document the scene, using notes, photographs, and measurements, as a homicidal hanging scene may not be suspected until later, at which point the original context of the scene is lost.

Purpose of Study

In a study of the Methods of Suicide used in Canada, between 1980 and 1982, hangings accounted for 24.52% of male suicides and 18.87% of female suicides (Health Canada, 1994: 32). Between 1990 and 1992, hangings accounted for 30.83% of male suicides and 22.26% of female suicides, an increase in this method of suicide, over the previous study completed ten years earlier (Health Canada, 1994: 32). Suicidal hangings, therefore, are increasing in frequency within Canada, and the death scenes of this type that scenes of crime officers and identification officers encounter have correspondingly increased. Thus, it is important to be able to distinguish, at sudden death scenes involving hangings, the physical evidence consistent with a self-inflicted act, such as suicide or autoeroticism, from the physical evidence consistent with a homicidal hanging.

Because homicidal hangings are so rare they pose a risk to investigators. As Püschel et al., note "lack of precise examination at the hanging site poses the risk that an indictable offence could go unnoticed" (Püschel et al., 1984: 141). The hypothesis of this study is that the physical characteristics of suicidal hanging death scenes are different and distinguishable from homicidal hanging death scenes, due to the differential treatment of the ligature and suspension beam at each type of scene. Thus, the aim of this study (distinguished as Phase II), is to quantify and qualify the physical features characteristic of homicidal hanging death scenes, typical of drag or haul-up type hangings. Phase II of this study provides a comparison to the initial Phase I study involving suicidal or drop-type hangings (called static falls). Phase II also examines the suicidal type hanging trials alongside the homicidal-type hangings (called drags) to apply the knowledge and experience gained from the trials in Phase I to improve the reliability of the study. The results of this study will be useful to scenes of crime and identification officers, providing them with characteristics to investigate the ligature, and suspension point of the hanging, and thereby determine the manner of death with greater accuracy.

A necessity for this type of proactive research has already been demonstrated. The Metro Toronto Police Services completed a few hanging trials in response to a coroner's inquest into a suspicious hanging death (Shearer, personal communication), however this is considered reactive research.

This type of practical study in the field of suicidal and homicidal hangings has not been found within the literature to have ever taken place. The closest that has been found in the literature are German articles from the Criminology Archives (Archiv für Kriminologie) that describe reconstructions of homicidal hanging scenes on the original suspension beams to determine the circumstances surrounding the victim's deaths, as previously mentioned (Popp, 1931; Klauer, 1933). Thus, proactive research in this area is beneficial, for the suspicious hanging deaths that are encountered, and for an understanding of how to improve hanging death scene investigations.

Materials

The Gallows

Using the gallows that was constructed for Phase I of this project, modifications were made by Staff Sergeant Pat Downey, to facilitate both the suicidal and homicidal type hanging trials (refer to Nicholls, 2000 for original design). The main changes from the original design involve the movement of the winch connected to the main rope (used to raise and lower the "dummy") to a post inside the gallows, and the addition of another winch, on an opposite post, used for the homicidal type drag trials (Diagrams 1 and 2; Photos 1 and 2). The gallows was also moved outside, and a new beam to suspend the pulley was added, increasing the height to 3.873 m (Diagram 1, Photo 3). The width and length remained the same, at 1.504 m wide and 1.581 m long, respectively. Measurements were taken using the MM30 Laser measuring device.

Ligature ropes were looped three times around the suspension beam for static fall or suicidal type hanging trials and the end was tied around two hooks drilled into the gallows, allowing the rope to tighten upon itself during the hanging trial (Photo 4).

The "Crash Test Dummy"

To accurately portray the weight of human, a simulation male crash test dummy weighing 70.27 kg (154.6 lbs) was constructed using a burlap army bag filled with sand and dirt, and held together with 1" link chains (Photo 5). The chains were held around the bag with cable and plastic ties, and joined at the top with a padlock, which was connected to a D-ring with a loop, in turn connected to the spring-loaded clasp (Photo 6). The original crash test dummies used in Phase I were returned to Transport Canada. In order to study a greater sample for data analysis, the decision was made to limit this portion of the study to the heavier "male" weight, allowing for more trials.

The Suspension Beams

Suspension beams used in the hanging trials were purchased from the Simcoe Block store in Barrie. Kiln treated 2" x 4" x 8' spruce boards were used, and each board was preformed to uniform standards, routered on the two sides in contact with the hanging ligature, using a new ¼" bit (Photo 7). This resulted in rounded edges that allowed the rope to pass over easier, and was a uniform standard from which the indentation made by each hanging trial could be measured. Hand clamps were used to affix each suspension beam to the main suspension beam of the gallows. Each individual suspension beam could then be removed after a set of trials and indentation depths measured.

The Ligatures

The ligature material chosen for the study was 3/8" three-strand twist polypropylene rope (Photo 2). Polypropylene rope was chosen because it is a relatively common and inexpensive rope, with intermediate stretch, that would likely not break or snap during hanging. In order to study a greater sample for data analysis, this portion of the study was limited to this diameter of rope, allowing for more trials.

For static fall trials, the rope was tied into the metal loop of the D-ring, using a noose knot (Diagram 3, Photo 6) which tightened during hanging. The other end of the rope was looped three times around the suspension beam and then tied off in the manner mentioned previously, around the metal hooks. The amount of rope used for each ligature was enough to facilitate a 0.5 m drop.

For the drag trials, the rope was looped into the winch and turned approximately eight times, to wind it onto the spool (Photo 2). Then the remaining length of rope was tied off into the metal loop of the D-ring attached to the dummy, and 0.5 m was measured on the rope to determine the drag length.

The Digital Calipers

The digital calipers used for the entire study were Pro-Max Digital Calipers, made by Fred V. Victor Fowler Company Incorporated (Photo 8). Each measurement was taken to the two decimal places shown in the display of the calipers, equal to 1/100th of a millimeter. For measurement of the indentation depth made in the wood suspension beams the squared end of the depth armature portion of the caliper was used.

The Custom Designed Jig

To accurately measure the indentation depths made in the wood, a custom designed jig was fashioned to hold the calipers in position, at a constant angle, during measurements (Photo 9). It was constructed of a piece of angle iron, with another piece of metal welded on and two nuts/bolts to tighten the calipers firmly against the jig. A hole was drilled into the angle iron so that the squared end of the caliper could be viewed when measuring the depth of the indentation.

Photographic Equipment

To photograph the suspension beams and ropes, both before and after trials, a Bronica ETRSi camera was used to do 1:1 black and white photography using TMAX 100 Kodak professional film (Photo 10). A Wild M420 Makroskop microscope with a 35 mm camera attachment, the Photoautomat MPS45, was used to do microscopic black and white photography, using TMAX 132-24 professional film, with magnification up to 48 times (Photo 11). My personal 35 mm camera, a Minolta, was used to take some of the colour photos of the gallows and equipment, and the remaining photographs were taken using a Sony PC10 digital videocamera. Black and white film developing was completed by the researchers, at the Technical Identification Services Unit, in Barrie. Infrared photography was completed with a Sinar field camera using 4” x 5” professional Kodak film, and IR photo developing was completed by the researchers, at the TISU, Barrie. Infrared examination was also completed using a Sony PC100 digital videocamera.

Fingerprint Lifting Tape

Tapings of the indentations completed after each trial were done using Remco brand fmgerprint lifting tape. These tapings were then placed on black background cards, using a rubber roller to eliminate air pockets, for later analysis.

Ultraviolet Light Analysis

The indentations were examined after removal from the gallows using the Omnichrome portable ultraviolet light source. Using different colours from the spectrum the boards were examined for rope transfer material.

Methods

Two types of trials were conducted in this study. The physical characteristics of the static fall type of hanging, consistent with a suicide, and the drag type of hanging, consistent with a homicide, were examined. For the hangings, each trial of 3/8" polypropylene rope was either dropped or dragged 0.5 m, and fifteen trials of each type of hanging were conducted on the same board. Seven and a half boards were used in the study, completing trials until there was no rope left.

For each trial a new length of ligature rope was used. Each wood surface was preconditioned to have rounded corners and even surfaces so deviations from the normal after the hanging trials could be measured, and errors eliminated. One type of ligature knot was used to hang the dummy (Diagram 3).

Control measurements of the boards, after routering, were taken prior to the hanging trials, along both sides of the board, namely the “ligature” and “opposite” sides (Diagram 4). This was completed using the custom designed jig and the digital calipers, and fifteen measurements were taken along each side, along all eight boards. The five centimeters at each end of the board was marked off and not used for control measurements or photographs. Three photographs each at 1:1,8.75 times and 20 times magnification were taken at predetermined areas on each board for control purposes. Similarly, fifteen photographs along a control section of rope were taken at 30 cm intervals, to represent the condition of the original rope prior to hanging trials.

The Static Fall Description

A complete static fall hanging trial, from start to finish, was a lengthy process. The dummy was raised to the appropriate mark on the main rope, with the winch. A piece of rope for the ligature was measured off and cut. This was tied around the metal loop of the D-ring, using the noose knot. The other end of the ligature was looped three times around the suspension beam and wrapped around the metal hooks.

The dummy was then raised using the winch to the correct height for the drop, and a crowbar was used to unlock the spring-loaded clasp. The dummy fell 0.5 m, and a notation was made as to the quality of the trial, or if any problems occurred. The main rope was lowered using the winch and the clasp was inserted in the metal loop, and locked. The dummy was raised to release the tension fiom the ligature rope and suspension beam, and the ligature knot was cut off. This end of the rope was then immediately retied to designate it as closest to the dummy, for orientation during later examinations. Using a black felt marker, the trial number was marked directly on the suspension beam, under the indentation mark on the "ligature side".

The points of compression on the first loop of ligature rope around the suspension beam were marked between two pieces of red evidence tape, for later photographic analysis. The ligature was removed fiom the suspension beam, and the rope was taped together into a bundle in areas away from the rope in contact with the suspension beam, marked using the trial identification system, and placed into a box.

A taping of the indentation area on the ligature side of the suspension beam was then completed, using the fingerprint lifting tape. A piece of tape was removed fiom the roll and placed over the curvature of the board, to encompass the ligature side of the indent. Using the rubber roller, the tape was flattened to remove air bubbles and pick up as much transfer material from the board and any rope fibres that may be present. The tape was then lifted off and placed onto a black background card, using the roller to remove any air pockets. It was marked using the trial identification system on the back, and stored for later analysis.

This process was then repeated for the next fourteen trials, and then the fifteen drag trials were completed on the same board. After the thirty trials a new board was used.

<u>The Drag Description</u>

The drag trials using the second winch on the gallows, were completed to examine the results of a simulation homicidal type hanging. Each drag trial was completed in between the static fall trials, so that a completed board had an alternating set of thirty trials down its length. The dummy was raised to the appropriate mark on the main rope. A piece of rope for the ligature was measured off and cut. One end was placed in the winch and the handle was turned approximately eight times, to wind some of the rope onto the winch. The free end was placed over the suspension beam, and tied off around the metal loop of the D-ring, using the noose knot. Using the winch, the slack in the rope was taken up, until it was just taught, with one person making sure the rope did not touch the suspension beam during this process. Using a black felt marker, the rope was marked with a 0.5 m increment, just under the suspension beam on the ligature side, and using the winch, was cranked or dragged up exactly this distance.

To release the tension on the ligature rope and suspension beam, the other winch was used to take up the slack created on the main rope and raise the dummy slightly, so the ligature rope could be cut off. This end of the rope was then immediately retied to designate it as closest to the dummy. Using a black felt marker, the trial number was marked directly onto the suspension beam, under the indentation mark on the ligature side. The ligature was removed fiom the suspension beam and taped together into a bundle in areas away fiom the rope that was in contact with the suspension beam, marked with tape using the trial identification system, and placed into a box.

A taping of the indentation area on the ligature side of the suspension beam was then completed, using the fingerprint lifting tape. A piece of tape was removed from the roll and placed over the curvature of the board, to encompass the ligature side of the indent. Using the rubber roller, the tape was flattened to remove air bubbles and pick up as much transfer material fiom the board and any rope fibres that may be present. The tape was then lifted off and placed onto a black background card, using the roller to remove any air pockets. It was marked using the trial identification system on the back, and stored for later analysis. This process was then repeated for the next fourteen trials.

After a set of trials was completed, the suspension beam was removed fiom the gallows, and measurements of the indentations on both the ligature and opposite sides were taken using the digital calipers and custom designed jig. Three measurements were taken at the deepest part of the indentation mark on both sides. These measurements allowed for a comparison of the depth of the indentations created during each type of trial. Examination for rope transfer onto the boards and indentations was completed using the Omnichrome portable ultraviolet light after completion of the trials.

The tapings taken during each trial were examined under the microscope at varying magnifications for rope fibre transfer material. The tapings were then scanned into a computer using a Hewlett Packard ScanJet 4C scanner, and brought up into Autosketch version 2.1, a drawing software. In this program, the tapings were analyzed by drawing a free-hand perimeter around the outline of the indentation (Diagram 5), and asking the software to calculate the area (cm^2) and perimeter (cm) of each trial (Diagram 5) on the ligature side. This allowed for comparison of the differences between the static fall and drag trials in the size of the indentation.

Photographs at the macro (1:1) and microscopic levels were also completed after the trials, on both the ropes and boards, to demonstrate the changes that take place after a hanging trial. Infiared photographs of the indentations on the boards were completed at the 1:1 level, and the indentations were also examined using the IR light attachment of the PC100 digital video camera.

Trial Identification System

To identify each trial, suspension beam indentation, and ligature rope, a letter and number system of identification was devised. Each trial was given a board identifier (ie. B#l, B#2, etc) and a number/letter system to distinguish between static falls and drags. Static falls were designated using the letter “a” and drags were designated using the letter "b". Therefore, for each board there were fifteen static fall trials numbered 1a to 15a, and fifteen drag trials numbered 1b to 15b. For example, B#3-7a would designate the seventh static fall trial on board number three.

Results

Observations

Omnichrome

After trials were completed on Board #1 and #2, the indentations were looked at under different colours of the ultraviolet spectrum using the Omnichrome portable UV light source. It was hypothesized that rope fibres broken off of the ligature during the hanging trials may be more readily visible under this light source, if they were not picked up by the tapings. However, no fibres were observed for either Board #1 or #2, and this test was dropped from the remainder of the trials.

Infrared Photos and Light

Using both Infrared photography and an IR light source from the Sony PC100 digital videocamera, the indentations were examined for rope fibres and more visible grooves or striations caused in the wood surface by the passage of the individual rope fibres over the wood. Neither the photographs nor the IR light source yielded any remarkable results, and these tests were subsequently dropped from the remainder of the trials.

Indentation Tapings

Initially the tapings were taken with the idea of counting the number of rope fibres transferred on the ligature side of the indentation during the hanging trials, using the Wild microscope. Three 1 cm^2 blocks were to be counted across each taping and a tally of the number of fibres in each block would be kept, to determine where the fibres were more likely to be found, and in what numbers. However, it was often not possible to distinguish rope fibres from the wood fibres that were also picked up during the taping or any other fibres (i.e. clothing fibres or dust) that may have adhered to the board, and subsequently the taping. Although many efforts were made to keep the boards free from outside fibres and contamination, a few red and blue fibres were observed, and the yellow polypropylene fibres were difficult to distinguish. This test was subsequently dropped from the remainder of the trials, as it was very time consuming and yielded poor results. The indentations were still taped, however, as the calculation of the area and perimeter using the Autosketch program, was an important discovery to the project (see Description of Results, below).

Cross-Section Analysis

A sample board was taken for analysis to Dr. Paul Cooper, University of Toronto, Faculty of Forestry. He examined the indentations under a higher power microscope, but was unable to observe anything beyond what had already been discovered about the indentations. He did, however, have the idea to cut through the cross-section of the indentation using a band saw. Dr. Cooper observed that the “densification” or compression of the wood tissue is greater in the static fall trials and similarly, that significant "failure" or breakage of the wood layers is only evident in the static fall trials. The drag trials exhibit minimal to no observable failure.

In the control photograph of the cross-section of wood after routering, no densification is observed (Photo 12). In comparison, the cross-section of the ligature side of a static fall trial (Photo 13) is observed to have the greatest amount of densification. Similarly the densification on the opposite side of the static fall trial is also quite apparent (Photo 14). The cross-section of the opposite side of a drag trial is pictured in Photo 15, and shows minimal densification of the wood layers, and a very small indentation, while surprisingly, the ligature side (Photo 16) of the drag trial has hardly any visible densification. This result was unexpected, as it was hypothesized that the ligature side of the drag trials, closest to the dummy, would bear more of the weight than the opposite side, however the reverse appears to be true.

Examples of failure in the wood layers, or fracture, of the wood during a static fall is evident in Photos 17 and 18, where there is a much deeper indentation. This visual characteristic is only observed to be remarkable in the static fall trials.

Dr. Cooper also suggested examining a thin section of the indentation cross-section, to determine if there were changes at the cellular level of the wood due to the different types of hanging trials. After softening the wood with a drop of water, he used an Exacto knife to remove a thin strip of the wood and then placed a droplet of phloroglucinol on the wood, and mounted it on a slide. Phloroglucinol is a liquid that stains the lignin in the wood cells red/pink for observation under a transmission light microscope. Examining the samples that Dr. Cooper created, we were unable to observe anything remarkable that was characteristic of either a static fall or drag trial, at the cellular level. It was also difficult to know if any changes were due to the cutting action of the Exacto blade. Changes at the cellular level are still being examined using different cutting methods, as are calculations of the area of densification in the cross-section to characterize a static fall from a drag trial (refer to Webster, 2001 for results).

Dr. Cooper also remarked that the indentations on these types of treated wood boards, if exposed to a significant amount of water, will rehydrate and the wood will bounce back, appearing as if there was never an indentation there. This is an important observation for hanging scenes that may become exposed to rain water (such as in the doorway of a barn or garage), and in cases such as these, the information should be recorded, and if necessary, preserved by covering with plastic to keep the water off. He noted that this does not apply to trees, as they are living, so they will retain their shape and damage despite being wet.

Photographic Analysis of Indentations

Representative control photographs of the boards prior to the hanging trials were taken at the 1:1 level (Photos 19-21) and at higher magnification (Photo 22) to represent the condition of the wood prior to the hanging trials. In comparison, representative examples of static fall indentations on the ligature side at the 1:1 level are Photos 23 and 24. Note the deep indentation and failure of the wood layers, seen better in Photo 25, under 8.75x magnification. An example of the opposite side of a static fall indentation at the 1:1 level is Photo 26; it is notably shallower and has less significant fracture of the wood.

Representative examples of drag indentations on the ligature side, at the 1:1 level, are in Photos 27 and 28, while an example of the opposite side, which appears to be deeper, is Photo 29. The amount of failure of the wood layers in a drag trial is observed at 8.75x magnification, but is very minimal (Photo 30).

The striations in the indentations evident at the 20x magnification level, caused by the passage of the individual rope fibres over the board during the trials, seem to be virtually indistinguishable between the two types of trials (Photos 31 and 32).

A double or triple indentation was also sometimes observed, but only in the static fall trials due to the rope being looped three times around the suspension beam (Photo 33). Each successive indentation was shallower than the previous, and often the third, if visible, was very faint. Multiple indentations were not observed in the drag trials, as the rope only passed once over the suspension beam. It is important to note however, that if a victim was dragged up and then tied around the suspension beam, it is possible that multiple indentations may appear, especially if they are left hanging for a length of time.

Photographic Analysis of Wood Fibre Directionality

As stated by Goddefroy (1923: 226- 227), a suicidal hanging will exhibit "wood fibres directed ...downward on both sides", while a homicidal drag type hanging will exhibit "wood fibres... bent in the direction of the pull.. .upwards on one side.. .downwards on the other side". This directionality of wood fibres on the suspension beams was observed to be true and was recorded photographically.

Examples of broken wood and fibres directed downward on the ligature side of the static falls are seen in Photos 34-39. Examples of fibres directed downward on the opposite side of the static falls are seen in Photos 40 and 41.

Fibres directed upwards on the ligature side of the drag trials are observed in Photos 42 and 43. Downward directed wood fibres on the opposite side of the drags are observed in Photos 44-46.

Photographic Analysis of Rope Fibres

Representative photographs of the selected control rope are observed in Photos 47 and 48, at the 1:1 level, showing a clean, new length of rope. The control rope at 8.75x magnification is Photo 49, and at 20x magnification is Photo 50.

In comparison, the compression or flattening and filamentation or breakage of the rope fibres, in a static fall trial rope is observed in Photos 51 and 52. The filamentation and flattening of the rope fibres in a drag trial is somewhat similar, (Photos 53-55), however the extent to which the rope fibres are compressed in a static fall is much greater due to the force.

The best indicator of directionality in the trials was exhibited by the drag trial ropes, which often had snags in the length of rope that had passed over the suspension beam. An example of this is Photo 56, in which an individual fibre has been pulled out of the bundle of strands by the wood, and the close up of the snagged fibres' origin within the strand is Photo 57. These snags were the best indicator of directionality as they retained their positions after removal fiom the suspension beam, in the direction in which they had been pulled out.

Surprisingly in the drag trials, little transfer material fiom the wood of the suspension beam was observed, but in the static fall trials at the points of the first loop the most transferred wood splinters were seen.

An example of a rope fibre found within a drag indentation, rarely observed in either type of trials, was photographed at 20x magnification (Photo 58).

Raw Data

The numerical results of this study rest on four kinds of collected data from the hanging trials – depth of the indentation produced by the hanging trials, on the ligature and opposite sides, and calculation of the area and perimeter of the indentation tapings from each trial. The raw data of area calculations fiom the Autosketch program is in the descriptive statistics of Appendix G. The raw data of perimeter calculations fiom the Autosketch program is in the descriptive statistics of Appendix G. The raw data collected fiom the fifteen control measurements taken on each side of the board is in the control descriptive statistics in Appendix

G. The raw data collected from the indentation measurements is in the descriptive statistics in Appendix G.

To calculate the maximum indentation depth on either the ligature or opposite side, the fifteen control measurements were averaged and subtracted from the average of the indentation measurements on that side, and then the standard deviation was recalculated using the formula:

$$\pm\sqrt{\frac{(s_1^2)}{(n_1)} + \frac{(s_2^2)}{(n_2)}}$$

Statistical Methods

Statistical calculations were completed on the Minitab Statistical Software package, Enhanced Version, Release 9.1 for Sun. Raw data was entered into the program, and descriptive statistics were calculated. Minitab uses the sample standard deviation to calculate deviation from the mean.

Summary statistics of the area (Tables 2 and 3) and perimeter (Tables 4 and 5) measurements of the indentation tapings are within Appendix C. Summary tables of the descriptive statistics of the control board measurements (Tables 6 and 7) and the calculated maximum indentation depth, after subtraction of the control measurement and recalculation of the combined standard deviations (the true indentation depths recorded for each board) are in Tables 8-11. The indentation measurements prior to subtraction of the control measurements (Tables 12-15) are also contained within Appendix C. The mean and standard deviations of each set of measurements were plotted in Charts 1 – 40, within Appendix D.

Description of Results for Area Measurements of Indentation Tapings

It was expected that the force generated in a 0.5 m static fall hanging would be greater than that generated during the drag hanging, thereby creating a larger indentation in overall area on the ligature side. This general trend was observed for all boards (Charts 1 and 2), and was statistically significant for all boards (Charts 3-7 and 9-10), except Board 6 (Chart 8). For static fall trials the mean area of the indentation tapings ranged from 3.290 ± 0.877 cm^2 to 6.135 ± 1.202 cm^2, while the mean area of the drag indentation tapings ranged from 1.8258 ± 0.3692 cm^2 to 3.613 ± 0.747 cm^2 While there is some overlap in the calculated areas, the static fall calculations are generally much larger, providing an important criteria to investigate suicidal from homicidal hangings. If a taping of the indentation is taken at a scene, and a reconstruction of a suicidal type hanging is completed on the original suspension beam, and another taping is taken, the comparison of indentation area between the two hangings will provide good criteria to distinguish a suspicious hanging death.

Description of Results for Perimeter Measurements of Indentation Tapings

Similar to the area calculations, it was expected that the force generated in a 0.5 m static fall hanging would be greater than that generated during the drag hanging, thereby creating a larger indentation in overall perimeter size on the ligature side. This general trend was observed for all boards (Charts 11 and 12), and statistically significant for six boards (Charts 13-14, 16-17, 19-20), however not Board 3 (Chart 15) or Board 6 (Chart 18). For the static fall trials the mean perimeter of the indentation tapings ranged from 9.524 ± 1.824 cm to 13.180 ± 1.132 cm, while the mean perimeter of the drag indentation tapings ranged from 6.436 ± 1.601 cm to 8.84 ± 1.011

cm. Similar to the area results, there is an overlap, but the static fall calculations are generally much larger for the perimeters of the indentations.

The calculation of the perimeter measurements would be more remarkable if the standard deviations could be decreased. This requires more practice with the Autosketch program, and careful collection of the perimeter of the indentation, perhaps by using the roller with more pressure, during the taping process, to collect the most information possible, Similar to the area calculation, if a comparative hanging is conducted, the calculation of the perimeter measurement provides another important characteristic to distinguish a suspicious hanging death, and could quickly be approximated using a ruler, without software such as Autosketch.

Description of Results for Indentation Depth Measurements

An analysis of the Control measurements taken prior to the hanging trials shows that the routering process is indeed a relatively accurate method of maintaining control across the boards (Charts 21 and 22). The initial depths for both the ligature and opposite sides of all boards are all approximately the same, suggesting that all boards were routered to be approximately the same evenness and height, as measured by the custom designed jig and digital calipers.

It was expected that due to the force generated by the static fall hangings, the indentation depths created would be deeper in these hangings, than the drag hangings. This general trend was observed for all boards (Charts 25-40) and was statistically significant for both the ligature and opposite sides, when comparing the static fall trials to the drag trials, for all boards. This result demonstrates that at the 0.5 m height, there is a significant difference in indentation depth created as a result of the rope being treated differently during the two types of hanging trials.

In comparison to the results of Phase 1 (Nicholls, 2000), which found that the weight of the crash test dummy could not be correlated to a particular indentation depth, it is possible from this set of results to correlate the indentation depth to treatment of the ligature in the different types of trials. This result is one of the most important characteristics for distinguishing a static fall from a drag trial, as results indicate that for the ligature side of static fall trials there are no average indentation depths less than 1.464 ± 0.0660 mm (Board 6, Chart 35), while for the drag trials on the ligature side there are no average indentation depths greater than 1.1322 ± 0.0564 mm (Board 8, Chart 39).

The static fall trials compare well to the result demonstrated for 3/8" polypropylene rope in Chart 45 of Phase I of the project (Nicholls, 2000). Using a slightly lighter male dummy (68.1 kg), and fifteen 0.5 m static fall hanging trials, the ligature side indentation was measured to be 2.2843 ± 0.3028 mm, falling within the average range of ligature side indentations recorded for all the static fall trials completed in Phase 2, from 1.4674 ± 0.0660 mm (Board 6) to 4.28 17 ± 0.1 133 mm (Board 5) (Chart 23). Thus, this comparison shows that using the same rope type and roughly the same weight of dummy, the same results were obtained for different board types (i.e. lumber yard versus scrap wood) and dummy styles (i.e. crash test dummy versus weighted burlap bag), illustrating continuity across both studies.

It was expected that the force generated by the dummy during both types of hangings would be concentrated primarily on the ligature side. This was found to be the general trend upon comparing the ligature and opposite sides for all the static fall trials (Chart 23). For all boards the ligature side of the static falls was significantly deeper than the opposite side, with the exception of Board 6, in which the opposite side was slightly deeper, although not significantly so. Contrary to expectations, however, the general trend in the drag trials was for the opposite side indentation to be deeper, and this was significant in five boards (Chart 24). Therefore, this suggests that the opposite side supports a greater amount of the force during the drag trial, a finding that is contrary both to the expectations of the trial and to the findings of the static falls. This result is an important characteristic if measurements of indentations reveal the opposite side is deeper than the ligature side, the hanging should be further investigated as potentially suspicious.

OMMPAC Survey

A survey of the sudden death hanging cases from 1999 and 1998 was conducted, using the OPP OMMPAC system and case files from Central Region, investigated by the Technical Identification Services Unit **(TISU)** in Barrie. Cases were selected that involved hanging as part of the mode of death, and those investigated by the Peterborough TISU were omitted, as their files could not be accessed. The survey involved recording as much information as possible from both the case file and the OMPPAC system, which records the investigating officers' notes. Based on characteristics that have been studied in both Phase I and Phase 2 of this project, the survey was set up to determine how investigators have recorded these scenes and whether the key characteristics such as ropes, knots, and suspension points were examined. Twenty-eight characteristics were recorded.

Survey Characteristics

The survey, in Appendix E, records what 'type of hanging' the coroner determined the death to be. 'Location of hanging' is the place where the victim was found hanging. 'Stepping aids' located near to the point of hanging were recorded in column three. The 'suspension point type' is the material that the ligature and body are found hanging from The 'ligature type' is the material used to hang the victim. The 'knot type' used on the ligature around the neck was recorded, if the ligature was a rope or other material that could be tied. The 'knot location' is the placement on the neck. 'Hair/clothing caught in ligature' describes if any materials were caught in the ligature around the neck. 'Complete or incomplete suspension' describes if the victim was fully hanging off the ground or not. 'Suicide note' describes if a note was found at the scene or not. 'Dirt/dust' describes if the victim had any dirt or dust on them at the time of discovery.

'Grooves' describes if the suspension point was examined for indentation marks or grooves created by the hanging. Similarly 'Fibres' describes if the rope or suspension point was examined for fibre directionality. 'Drag marks' and 'Signs of struggle' describe the general nature of the scene, and whether any observations indicate the victim was dragged or involved in a struggle. 'Measurements taken' records whether the investigating officers took any measurements at the scene. 'Photographs' records whether any officers took any photos at the scene. 'Main evidence' describes the main pieces of evidence seized at the scene or autopsy. 'Evidence kept' describes whether the report states where or for how long the evidence was kept.

'PM attended' describes whether the Identification Unit or SOCO officer attended the autopsy of the victim. 'Weight' and 'height' describe if these measurements were taken at autopsy or approximated at the scene. 'Lividity' and 'Rigor mortis' describe the condition of the body at the scene or at autopsy. 'Cause of death' is the cause determined by the pathologist at autopsy. 'Other injuries' describes any other remarkable injuries the victim may have had at the time of discovery or at autopsy. 'SOCO or Ident' describes which level of investigating officer attended the scene, either Scenes of Crime Officer or Identification Unit. 'Suspicious Case' describes if any characteristics recorded reflect a potentially suspicious hanging death, and if so, which characteristics. "NR" within the survey table means that the trait for that case was 'not recorded' on either the OMPPAC system or within the case file folder.

1998 Survey Results

In 1998, Barrie TISU investigated nine sudden deaths involving hangings (Appendix E). All were ruled to be suicidal, and five of the nine hangings occurred outside, using tree limbs as the suspension point. In four cases the existence of a stepping aid near the location of hanging was not recorded. Six cases used a type of rope as the ligature, but in none of the cases was the type of knot recorded. Case **#3** was the only case to have recorded the location of the knot, at the right of the neck towards the back. Interestingly, in Case #2, the left glove of the victim was caught under the ligature around the neck, found hanging from a tree limb. This case was the only one of nine in which a material was recorded under the ligature. In six of the nine cases, complete or incomplete suspension was not recorded. A suicide note was found in six cases, not found in two cases, and not recorded at all in one case. In both Cases #1 and #2 the victim was found to have bark on their pants, as they had apparently climbed trees to hang themselves from the limbs. Observations were not recorded for the remaining seven cases.

In the categories of grooves, fibres, and drag marks, no observations were recorded for any of the cases, suggesting that none of these factors were examined during the investigations. In six of the cases, officers reported that there were no signs of a struggle at the scene, however this information was not recorded at the remaining scenes. Similarly, in six cases measurements were taken, however in three cases this information was not recorded. In all nine hanging deaths photographs were taken, and the ligature was seized as evidence, often along with biological samples taken at autopsy. In only one case, however, was information recorded as to the location or status of the evidence seized, and in this case (#4) it was destroyed. Eight of the nine cases had either an Ident officer or SOCO officer attend the post mortem, however, in one sudden death hanging case an autopsy was not conducted, therefore no cause of death or other injuries were reported. Case #3 was the only case in which the weight, height, and lividity of the victim were recorded. In two cases the victim had rigor mortis, in one case the victim was frozen, and in the remaining six cases this characteristic was not recorded. The cause of death in the eight cases that had an autopsy was determined to be asphyxia, and in six of these cases no other injuries were apparent. Identification officers from the Barrie TISU attended all of these cases in 1998.

Overall, based on this analysis, the most suspicious case from the nine would be Case #2, as the glove being caught under the ligature next to the neck is very characteristic of a homicidal hanging. The bark on the pants of the victim in this case, however, is likely indicative of the victim climbing the tree and attaching the ligature to the limb himself or herself. Case #4 was interesting as the victim was found to be twenty feet off the ground, with no stepping aids (i.e. a ladder) present to assist this hanging, and no record of any bark on the pants. Case #5 was also unique in that a post-mortem was not conducted, therefore this case is missing all of the associated information that arises out of this type of examination, including a cause of death.

1999 Survey Results

In 1999, Barrie TISU investigated seven sudden death hanging cases (Appendix E). All seven cases were found to be suicidal hangings, as ruled by the coroner, and in comparison to 1998, only two hangings were from tree limbs outside, while the remainders were inside the house or garage. The use of stepping aids to facilitate the hanging was not recorded in three cases, and in two cases no stepping aid was found. Six of the seven ligatures were ropes or tie down cords, but the knot type was not recorded in any of the cases. The knot location in Case #1 was found to be on the right side of the neck under the ear of the victim, but was not reported for the remainder of the cases. Materials such as hair or clothing caught in the ligature around the neck were not recorded for any of the cases, and only in three cases was complete or incomplete suspension recorded. Any observance of a suicide note was not recorded for five of the seven hangings, and for all nine cases disturbances of dirt/dust were not recorded.

Details of grooves over the suspension beam and fibre transfer onto the ligature were recorded only in Case #7, by a very observant Identification officer, as this was the only case from all hangings surveyed to have both observations and photographs of these characteristics. Incidence of drag marks was not reported for any case. There were no signs of a struggle in two cases, and in the remaining five no observations were recorded. In five cases measurements were taken at the scene, however, in the other two cases it was not recorded whether measurements were taken. Photographs were taken in all cases, and in six cases the ligature formed part of the main evidence seized, along with other items such as bio samples, drugs, and a rifle. Case #4 however had no record of any evidence being seized. In five of seven hangings, the location or length of time the evidence was kept was not recorded. In five of the cases the post-mortem was attended by an officer from the Barrie TISU, in one case a SOCO officer attended, and in one case it was not indicated that the autopsy was attended at all. In Case #1 the weight and height of the victim was recorded, likely because the identity of the individual was initially unknown, but was not recorded for the remaining six cases. Lividity was present in five of seven cases, not recorded for the other two cases, and rigor mortis was only present in one case, one victim was frozen outside, and this characteristic was not recorded for the remainder of the cases. Cause of death was due to asphyxiation in all cases, except Case #6, where death was caused by a gunshot wound. Other injuries were not present in five cases, not recorded in one case, and only a skin abrasion and gunshot wound were noted for the others. The Barrie TISU attended all of the hanging scenes except for Case #4 in which a SOCO officer attended the scene.

Overall, based on this analysis of scene characteristics, the most suspicious case from these seven would be Case #6. The circumstances are very different, due to the apparent self-inflicted gunshot wound and then subsequent hanging, and because of this rarity the ligature and suspension beam should have been examined. The circumstances surrounding Cases #1 and #5 are also very interesting. In Case #1 the victim was initially unidentified, and in Case #5 a hostile homeless individual was found trespassing near the hanging scene, but stated that he/she had not observed or encountered the victim in the days prior to the hanging, Thus, other circumstances make these cases somewhat suspicious, however, as much of the information required to raise suspicions in all of the cases was often not recorded by the investigating officers, it is difficult to judge the characteristics for validity.

Discussion

Summary of Results

Phase I of the project examined static fall trials exclusively, using two different sizes of polypropylene rope, and two different dummy weights, with three different drop heights. Results from the examination of ropes after hanging trials indicated that it was not possible to correlate a particular amount of rope compression to determine a drop height or to determine an individual's weight. Remeasurement of the ropes after a period of time to determine relaxation concluded there is the possibility of change in diameter of the rope over time, and that measurements of the rope taken at a time after the initial hanging scene would not be representative of the original conditions at the scene. Thus, while this was an important discovery, Phase II data collection focused more on fibre directionality and rope diameter measurements were not collected, instead photographs were taken to provide a macroscopic analysis.

Indentation measurements of the static fall trials on the ligature side of the boards in Phase I determined that as drop height increased, the indentation depths also increased, up to 1.0 m and then decreased at the 1.5 m drop height. It was also found that because a particular depth of indentation could not be correlated to a particular weight, that it must be determined upon investigation whether the individual committed suicide or was the victim of a post-mortem suspension, as the depths were not significantly different between the weights. To collect a greater volume of data, Phase II focused on only one weight, one rope diameter and one drop height, to determine the differences in indentation depth between suicidal type and homicidal type hangings.

Phase II data collection considered a greater range of data collection methods, including photography, both macro and microscopic, tapings, and measurements of indentations. Attempts were made to use other instrumentation, such as the Omnichrome ultraviolet light and infrared lights, and to involve a multi-disciplinary investigation, using specialists such as Dr. Cooper, as in the examination of the cross-section of the indentations, both at the macroscopic and cellular level. This may ultimately prove to be an important part of the investigative process of sudden death hanging scenes, when more conclusive results are determined (Webster, 2001).

Phase II observational results (Table 1) indicate that at the macroscopic level, the amount of densification of the wood, in a cross-section of the indentation, is much greater in the static fall trials than the drag trials. The same result was found for the amount of visible failure in the wood layers. Additionally, it appeared that the densification was greater on the opposite side of the drag trials, than the ligature side, and the reverse appeared to be true for the static fall trials. Once more conclusive calculations are made, this opposing characteristic will provide another method to evaluate suspicious hanging death scenes.

Observation of the indentations at the macro and microscopic level, revealed differences in the amount of wood failure, as previously mentioned, and in the depth of the indentations between the static fall and drag trials, as proved by measurements. Analysis of wood fibre directionality was found to be consistent with Goddefroy's assessment of the rope passing over the suspension beam (1923: 226-227) – that in the suicidal type hangings the fibres were directed downward on both the ligature and opposite sides, while in the drag hangings the fibres were directed upwards on the ligature side and downwards on the opposite side (Table 1). The best indicator of rope fibre directionality in the drag trials was found to be the snags pulled out by the wood of the suspension beam, which retained their positions after removal from the suspension beam.

Quantitative measurements from the tapings yielded the result that both the area and perimeter of the ligature side of the indentations were generally larger for static fall trials, than for drag trials. Similarly, the depth of indentations calculated using the jig and digital calipers resulted in statistically significant differences between the static fall and drag trials, for both ligature and opposite sides, with the static fall trials being significantly deeper than the drag trials. In addition, measurement of the indentation depths confirmed the visual result that the ligature side was deeper for the static fall trials, and shallower for the drag trials.

A survey of 1998 and 1999 sudden death cases involving hangings, investigated by the Barrie Technical Identification Services Unit revealed that some pieces of critical information at the scene are often not recorded. Based on the results of this project and traits characteristic to each type of hanging scene (i.e. suicidal or homicidal), reviewed in the Introduction sections of Phase I and II, twenty-eight traits were examined for the sixteen cases reviewed in the survey. In six of the nine cases in 1998, 50% or greater (13 or more traits, not including the 'SOCO or Ident' and 'Suspicious Case' columns) of the traits were missing from the OMPPAC report and case file. In four of the seven cases in 1999, 50% or greater of the traits were missing. It must be noted however, that the OMPPAC system is a database management system, and not intended to be a comprehensive record management system Despite this, some officers' notes were reviewed, and pieces of information were still missing from their notes. The results of this survey indicate that there are differences in the amount and type of notes taken at scenes by different officers, and also likely some lack of knowledge of some of the key characteristics that distinguish homicidal hangings, probably because they occur so rarely. It is precisely for this reason that Püschel(l984: 141) advocates for a thorough examination of the hanging scene, and studies like this allow for review and education of characteristics.

TABLE 1. PHASE II RESULTS – COMPARATIVE SUMMARY.

SUICIDAL STATIC FALL HANGING	HOMICIDAL DRAG HANGING
• Deeper indentations in suspension beam	• Significantly shallower indentations
• Taping area and perimeter calculations larger, on ligature side	• Taping area and perimeter calculations smaller, on ligature side
• Wood fibres directed down on ligature side and down on opposite side	• Wood fibres directed up on ligature side and down on opposite side
• Densification and failure of wood layers greater in cross-section	• Minimal to no observable densification and failure
• Rope compression and filamentation in areas where first loop of ligature contacts suspension beam	• Some filamentation of rope fibres; snags in rope provide directionality of rope drag over suspension beam

Implications for Education of Hanging Death Scene Investigations

As a result of Phases I and II of this study, criteria for education of the physical characteristics to investigate sudden death hanging scenes have been reevaluated in accordance with the potential for distinguishing a homicide. To facilitate this, a data form has been created, described below, that outlines the criteria that should be recorded and examined at a suspicious sudden death hanging scene (Appendix F). It is also important to determine the circumstances surrounding the scene, by speaking to the witness who may have cut the victim down, for example, as they may have information regarding how the victim was hanging or whether they were fully suspended. In suspicious cases, or where circumstances seem suspect, it only takes a few more minutes to be complete and thorough in the investigation of the scene.

A. Scene Observations

Observations recorded at the scene of a suspicious hanging death are not that different from any other hanging death, however more focus should be concentrated on the ligature, knot, suspension point, and the associated indentation marks and potential for fibre directionality. Knot types and location should be recorded, as well as any material caught beneath the ligature, an important characteristic of homicidal hangings. Signs of a struggle or dirt/dust disturbed at the scene or on the victim are other indicators of a possible homicide. After the ligature has been recorded, sketched, and removed, the indentations on the suspension point should be described, photographed, and measured for depth. The same should be completed for control areas away from the hanging area along the same suspension point, to provide a comparison. Any fibre direction on the suspension beam should be recorded for the ligature and opposite sides, visible by using a microscope. If the suspension beam is made of wood the relative amount of failure should be recorded, and after all other measurements, observations and photographs have been completed on the suspension beam, the cross-section should be examined, if possible. Using a band-saw, a cut should be made through the middle of the indentation, and through the control areas, and an examination for densification should be completed. Any snags in the ligature or fibre directionality should be recorded, as well as any compression areas visible.

A taping of the suspension beam on the ligature side should be completed, at the area of the indentation under the first loop of the ligature. Using software such as Autosketch, the area and perimeter of this taping can be calculated, and is a useful comparative tool ifreconstructed hangings are completed on the same suspension beam.

B. Photographs

In addition to the photographs that are regularly taken at the scene and of the victim, the focus should be on extra photos of the knot type and location, as well as indentations and normal control areas on the suspension beam. Other photographs should record fibre direction or snags, if present, and the cross-section of the suspension, as previously mentioned. If the scene exhibits signs of a struggle, photographs should be taken of this, as it would be completed at other death scenes.

C. Measurements

Measurements should include the height of the victim, distance from the ground or floor to the victim's feet, and the distance from the ground to the knot of the ligature at the neck. Other measurements should include the distance of the knot at the neck to the suspension point, distance from the ground to the suspension point, and approximate length of the ligature. As well, if a stepping aid is present, the height of the step and distance from the top of the step to the feet of the victim should be recorded. Dimensions of the suspension beam and any other relevant measurements should be recorded. A basic diagram or sketch should also be created to illustrate the scene and its dimensions, as would be noted in any other hanging death.

D. Evidence Collected at Scene

Notes should be recorded as to what evidence was secured from the scene, if any, and where it was deposited, in case it needs to be found at a later date. Because evidence at the OPP is only held in suicide cases for three months, or often destroyed at the request of the family, a special effort should be made to keep the evidence of suspicious hanging cases, in the event of later reexamination.

E. Post Mortem Examination

The examination of the body at the post mortem should record basic information such as rigor and livor mortis, and whether these features correspond to the hanging position at the scene. The weight of the victim, and any other injuries present on the body should be reported, as they may be indicative a post-mortem suspension. Cause of death and estimated time since death should be reported.

Research Design

Research design problems encountered during the course of Phase II were minimal. Because most of the design problems were worked out of the gallows in Phase I, the major problem encountered for this project was how to analyze the tapings effectively. This was solved by experimenting with different computer programs to find a method to calculate the area and perimeter of the indentations, to determine differences between the static fall and drag trials.

Another challenge was the analysis of the cross-section of the indentations, and attempts to examine the wood at the cellular level for distinctive changes. This research, as previously mentioned, is still ongoing and will be finished within the next eight months (Webster, 2001).

Improvements over Phase I include a broader range of analyses that were conducted to extract the most amount of information possible from the trials. In addition, more efforts were made to control the study through photographs and initial measurements, prior to the hanging trials. This resulted in a greater comparative aspect to the study, and lower standard deviations.

Sources of Variability

Possible sources of variability within the study causing standard deviation include the routering process on the wood suspension beams, although as previously mentioned the routering was considered quite effective at maintaining control across the boards. In addition, all boards were purchased from the same lot at the lumber yard and were the same type of wood (spruce), resulting in uniform pieces of wood from which to begin the project.

Observer error, using the manufactured jig and digital calipers, may have occurred. However, measurements taken using the custom-designed jig eliminated the major source of variability within the measurement process, as a constant angle was maintained. One other source of variability may have been the squared end of the depth armature of the calipers. A less precise measurement may have occurred because the end was not pointed, however this should have only minimally affected the depth.

A source of variability among the tapings may have been due to observer error in using the Autosketch program, as a free-hand line was drawn to outline the area used in the calculations. In the future, it is suggested that a line is drawn on the top of the tape in a visible colour (i.e. white china marker) and then this is scanned in its entirety. This distinctly visible outline will result in an easier detection of the area, and a free-hand line can then be more accurately drawn using the Autosketch program, resulting in lower standard deviations.

The Future

Future studies in this area should focus on characterizing homicidal and suicidal hangings on different types of commonly used suspension beams (i.e. metal bar, tree limb) and using a greater array of ligatures (i.e. belts, electrical cord, dog leash). Now that the ground work for this type of proactive study has been laid, future data collection can expand the knowledge base by examining for similar characteristics in different materials. It is important that education and proactive learning result from these kinds of studies, prior to being confronted with the task of investigating a suspicious hanging death.

Conclusion

The aim of this study was to provide a practical investigation into the physical evidence consistent with suicidal and homicidal hanging acts, and more specifically, examine the ligature and suspension point morphology to determine characteristics that differentiate the two death scenes. A combination of observations and measurements from the hanging trials, and a survey of past cases and review of the literature, has resulted in an educational tool, the data form, to facilitate improvements in the study of the ligature and suspension beam at the scene of a suspicious hanging death. Education of these criteria to new investigators will hopefully result in an improved investigation of hanging death scenes, and may one day help to discriminate the rarely observed homicidal hanging.

Acknowledgements

First, I would like to thank the two most important people in this Phase of the project, and the CPRC for funding my research – Thank you so much.

- Paula Webster, my very dedicated student assistant, without whom this project could not have been completed, University of Toronto at Mississauga, Forensic Science and Biology student.
- Staff Sergeant Pat Downey, my mentor, Technical Identification Services Unit (TISU), OPP, Barrie. Thank you for your support and taking time out to advise me on this project.
- Canadian Police Research Council, Ottawa.

Next, I would like to thank these very important people, in no particular order, other than alphabetically, for their support, encouragement, and advice:

- Judith Brown, Eric Silk OPP Library, Orillia.
- Dr. Paul Cooper, University of Toronto, Forestry Department.
- Dr. Cummins, Forensic Science Coordinator, University of Toronto at Mississauga.
- Tim and Joe Downey.
- Oliver Foese.
- Identification Constables Gail Hankin, Tom Krezel, Scott Macleod, Carm McCann, Paul Rosato, and Special Constable Elena Vizza of TISU, OPP, Barrie.
- Julie Graham, Canadian Police Research Council (CPRC), Ottawa.
- Julie Grimaldi and Angela Eke, Operational Policy and Support Bureau, Orillia.
- Dr. Uli Krull, University of Toronto at Mississauga, Chemistry Department.
- Constable Don Shearer, OPP.
- Sergeant John Tod, Forensic Identification Services (FIS), Orillia.

APPENDIX A – DIAGRAMS 1 – 5

Diagram 1. Side elevation of hanging gallows.

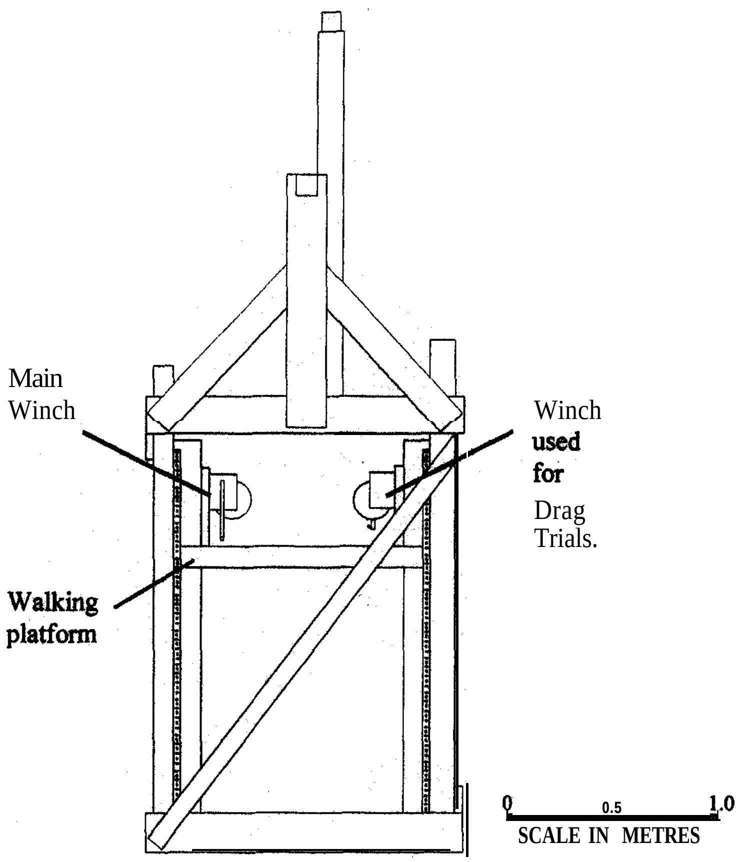


Diagram 2. Front elevation of hanging gallows.

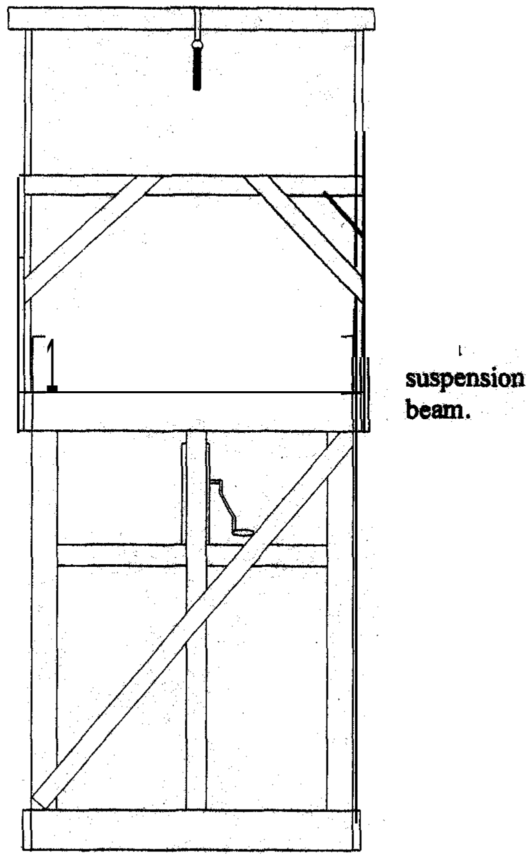
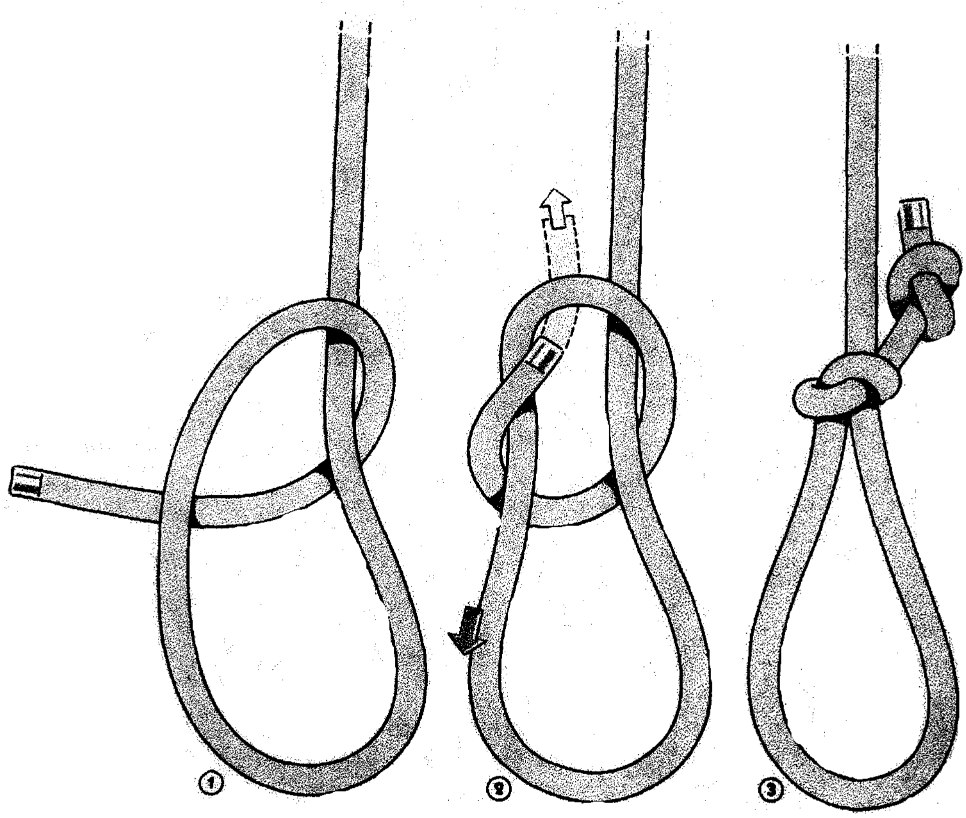


DIAGRAM 3. Diagram of Noose Knot, showing steps of tying. This knot was used in this study through the loop of the D-ring connected to the dummy.



Source: Owen, Peter (1996) <u>**Knots: The new compact study guide and identifier.**</u> Quintet Publishing Limited, London, Pg. 62.

DIAGRAM 4. Diagram illustrating the terms "ligature side" and "opposite side" used in this study.

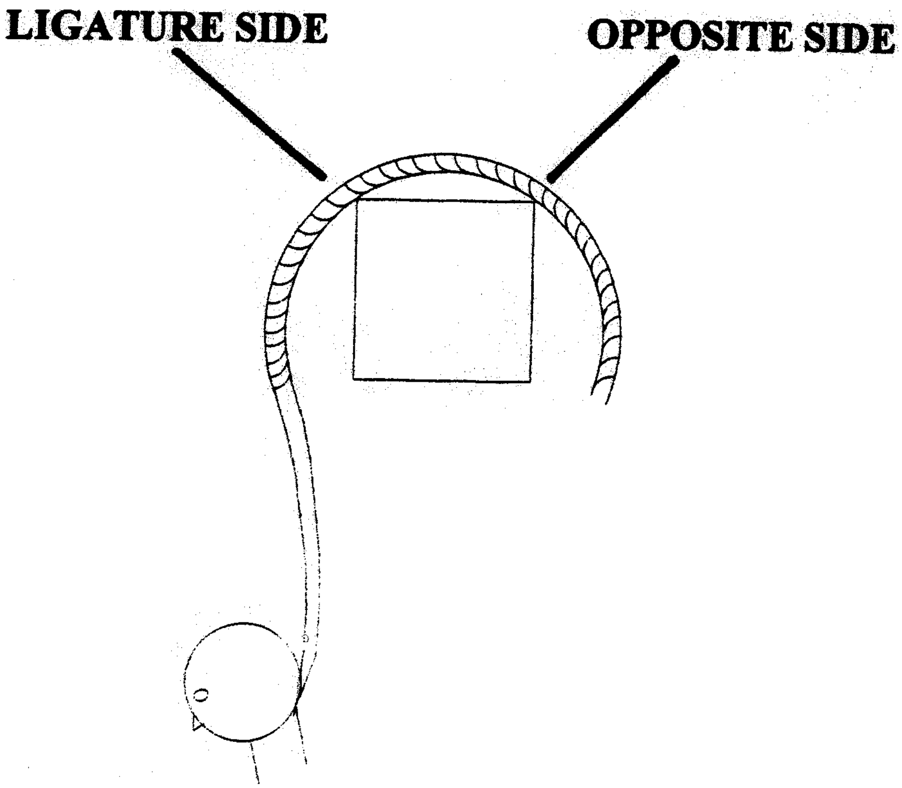
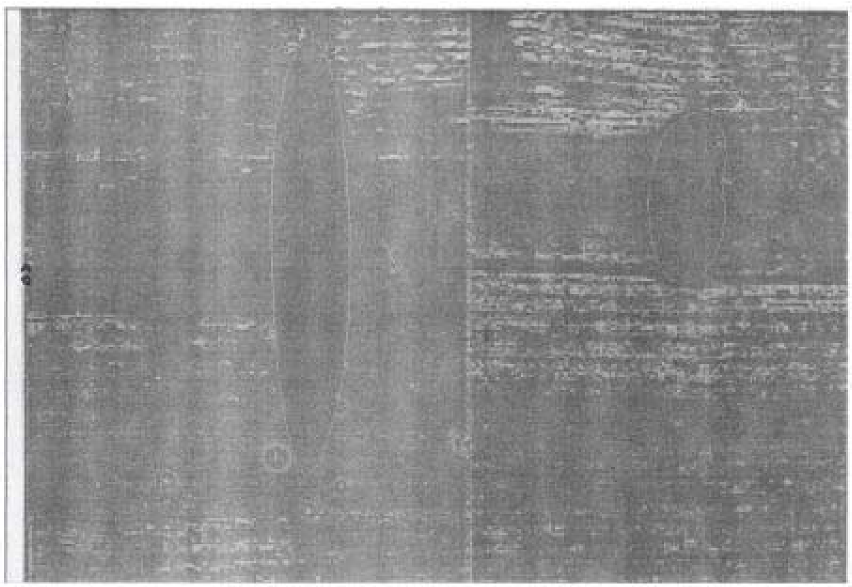


Diagram 5. Example of Indentation Tapings and Calculation of Area (A) and Perimeter (P).

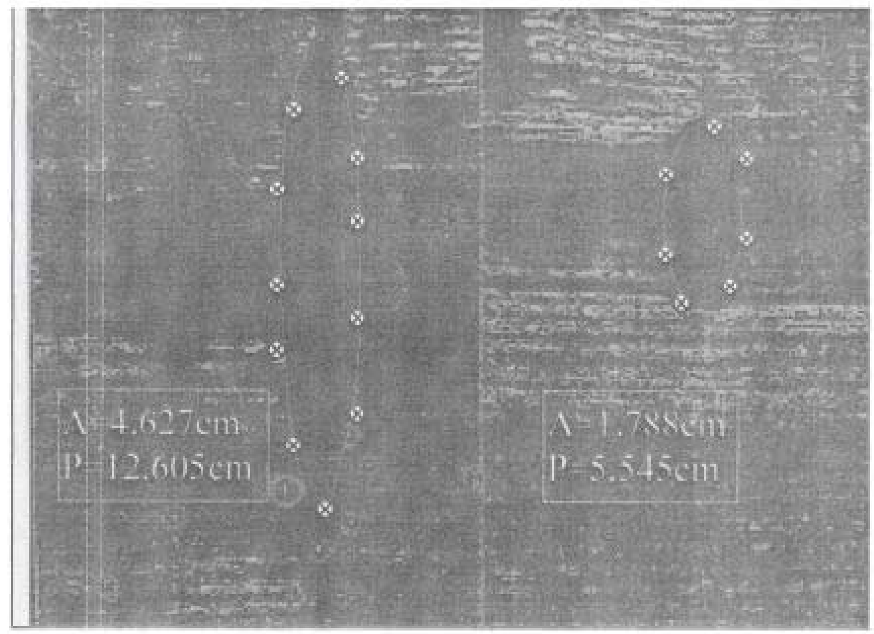
Free-hand drawing of perimeters.

A. Static Fall Taping. B. Drag Taping.



Calculation of Area and Perimeter.

A. Static Fall Taping. B. Drag Taping.



APPENDIX B – PHOTOGRAPHS 1 – 58

Photo 1. Winch connected to main rope.

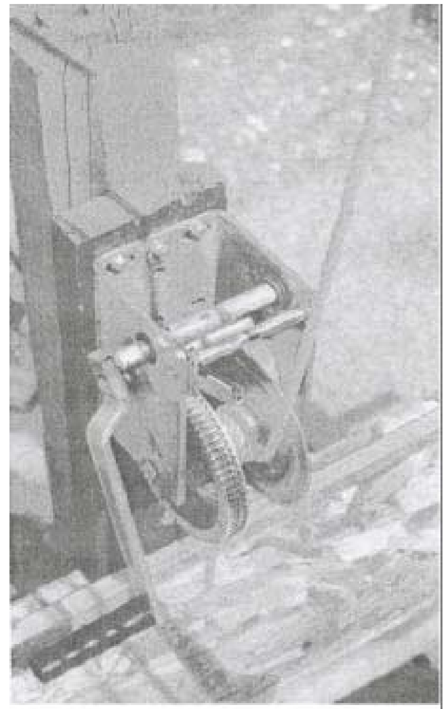


Photo 2. Winch used for drag trials. 3/8" polypropylene rope used in this study.

Photo 3. The gallows, with research assistant Paula Webster.

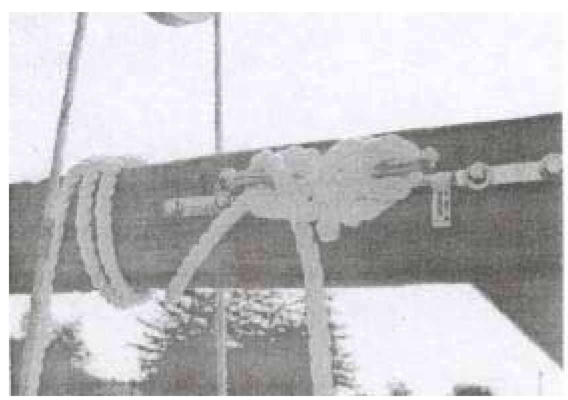


Photo 4. Example of how ligature rope tied around hooks and looped around suspension beam, in static fall trial.

Photo 5. The "crash test dummy", made of a burlap army bag, filled with sand.

Photo 6. The noose knot of the ligature rope, and spring-loaded clasp, padlock, rings, and chain arrangement.

Photo 7. Router used on the boards to preform the edges to a uniform standard.

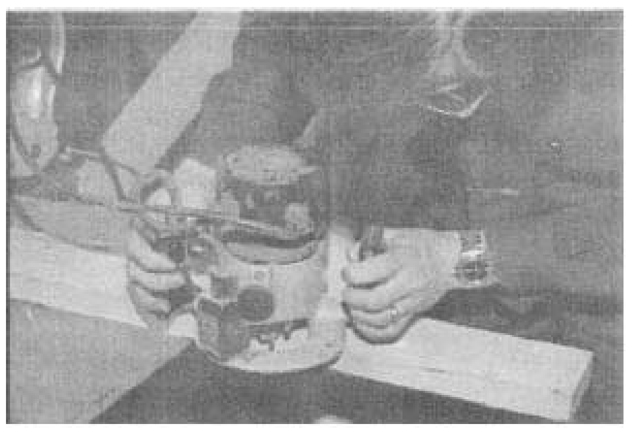


Photo 8. Pro-Max Digital Calipers used for measurement of indentations.

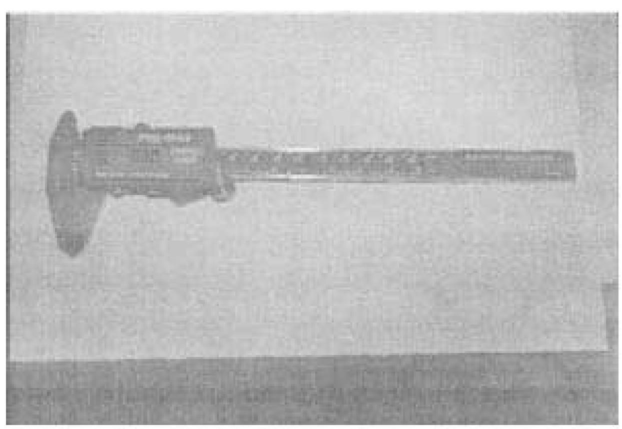
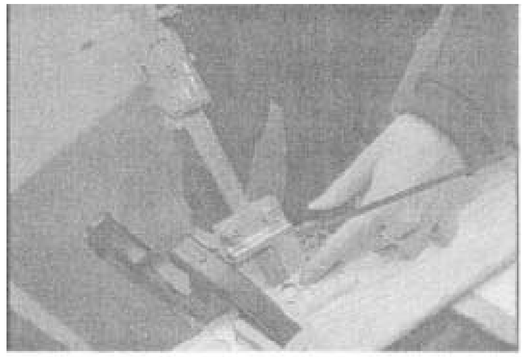


Photo 9. The Custom-Designed Jig, used to measure indentations, and hold the digital calipers at a constant angle.



Custom **Designed Jig**

Photo 10. The Bronica camera, used for 1:1 photography.

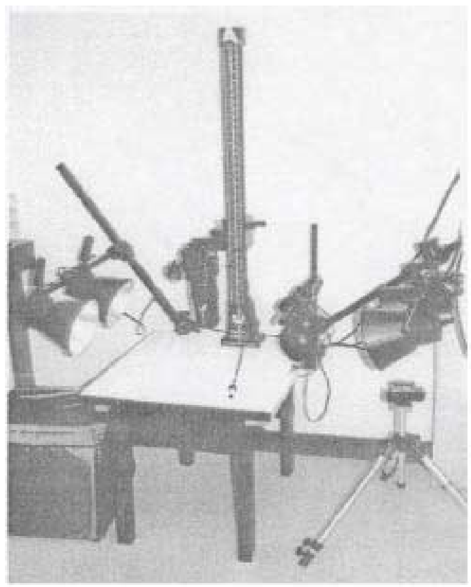
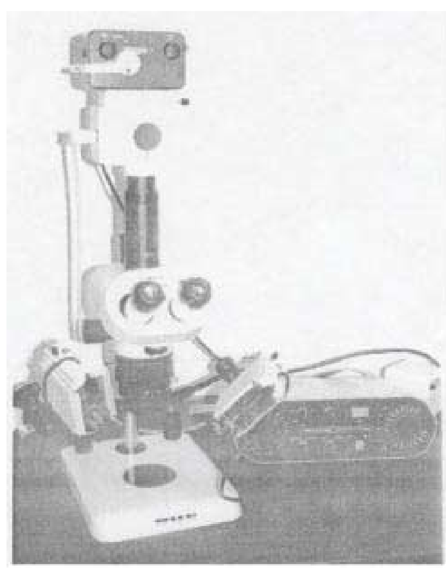


Photo 11. Wild microscope, with 35 mm camera attachment, used for black and white microscopic photography.



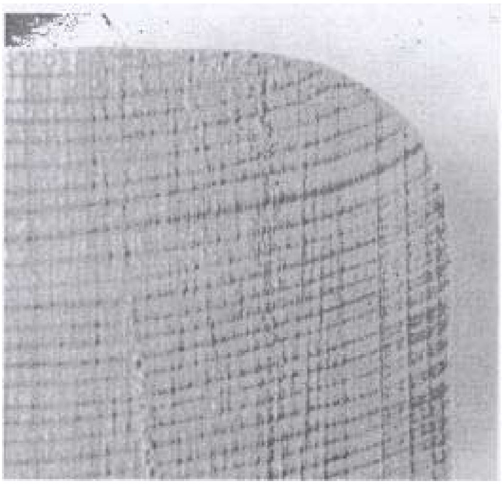


Photo 12. Control sample of cross section, no densifkation of wood tissue.

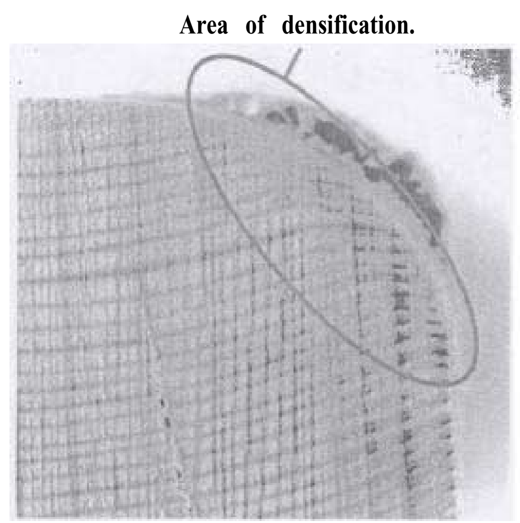


Photo 13. Ligature side, static fall trial, greatest amount of densification.

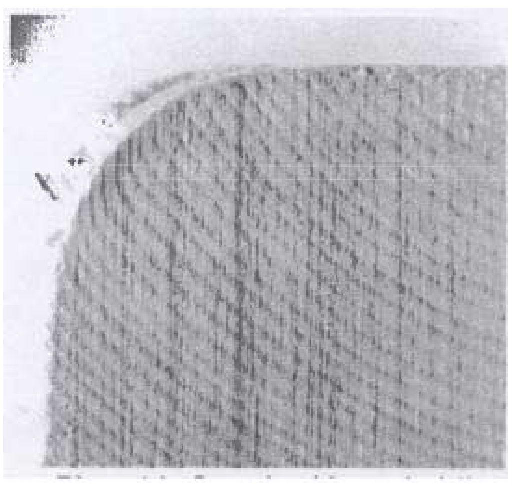


Photo 14. Opposite side, static fall exhibiting area of densification.

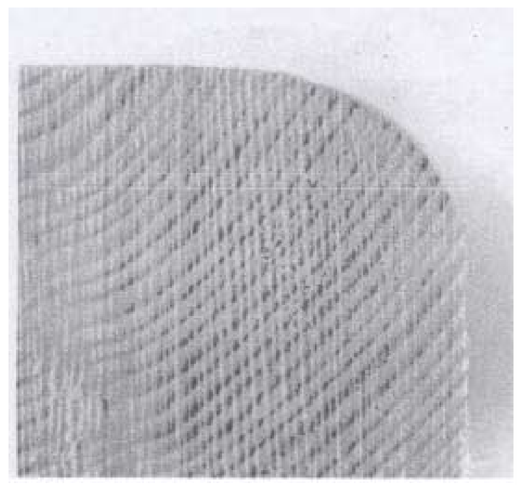


Photo 15. Opposite side, drag trial, minimal area of densification.

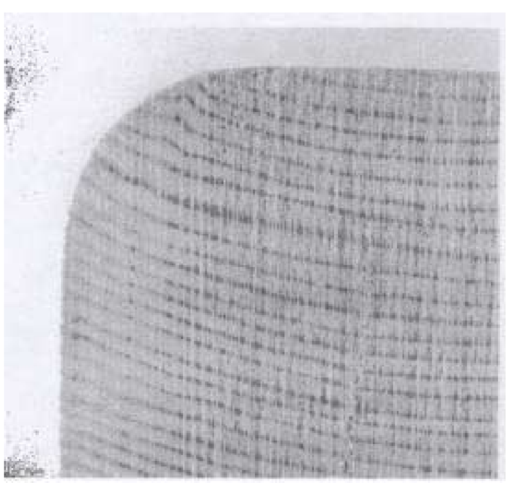


Photo 16, Ligature side, drag trial, hardly any visible den&cation.

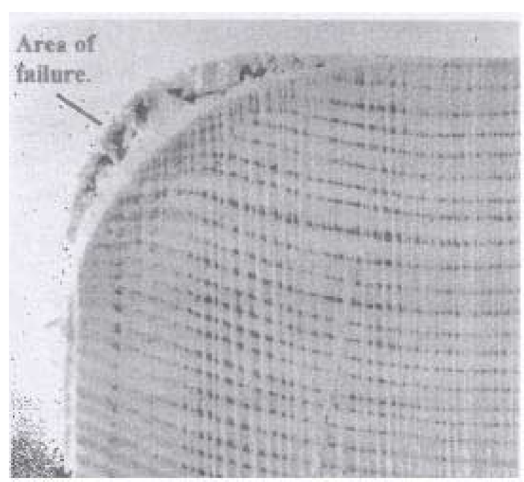


Photo 17. Failure in the wood layers of static fall trial.

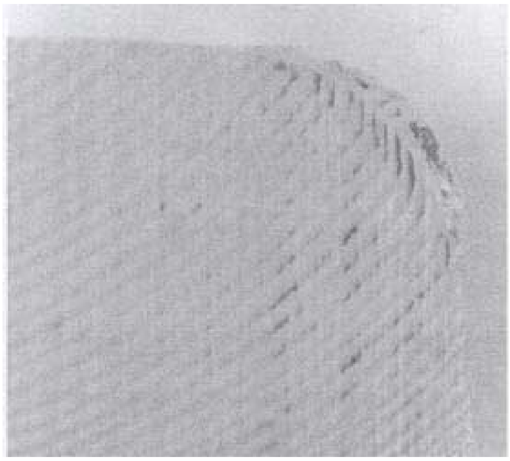


Photo 18. Another example of failure in wood layers of static fall trial.

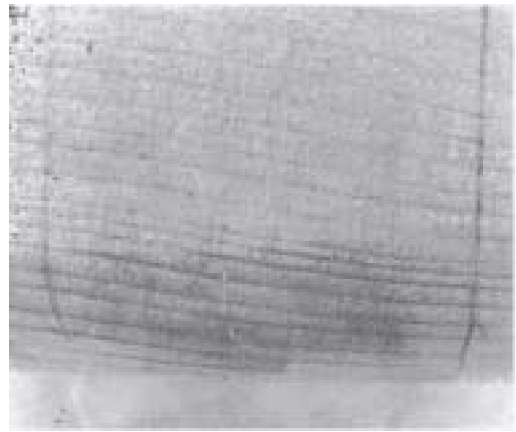


Photo 19. Control area, prior to trials.

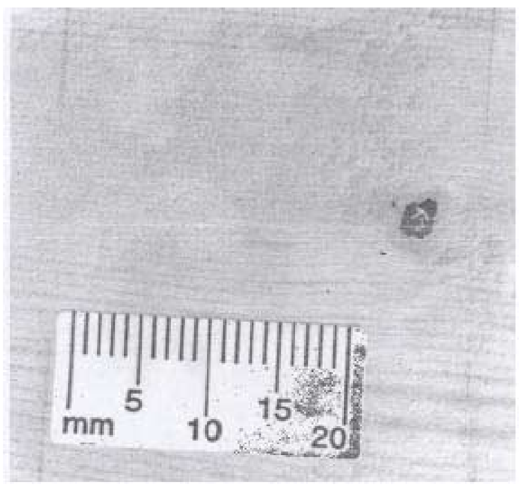


Photo 20. Control area, flat surface of board.

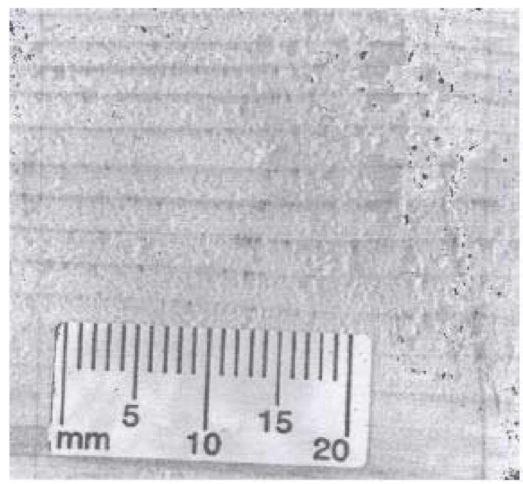


Photo 21. Control area, flat surface of board.

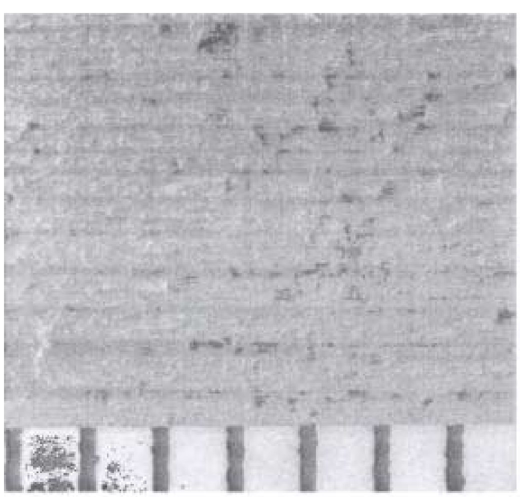


Photo 22. Control area of board (8.75x).

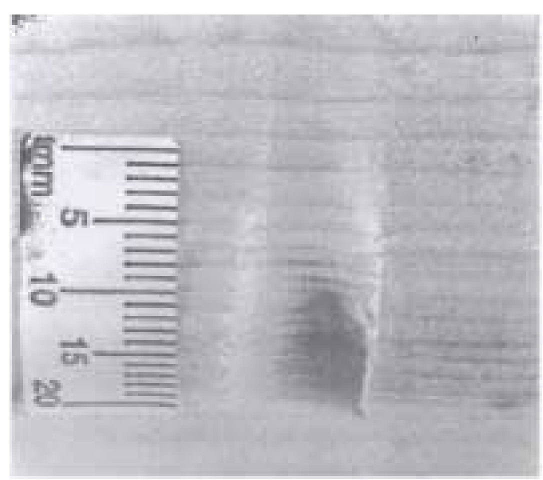


Photo 23. Example of static fall indentation, ligature side.

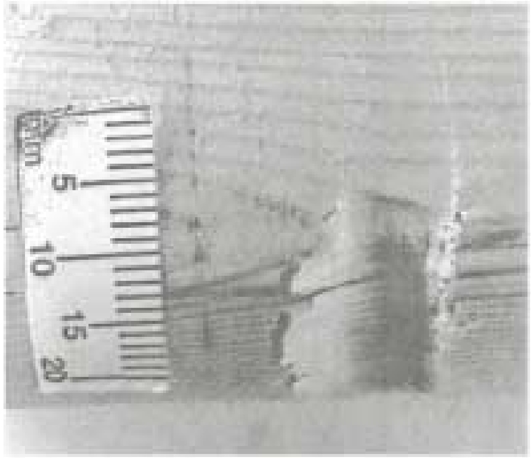


Photo 24. Example of static fall hanging indentation.

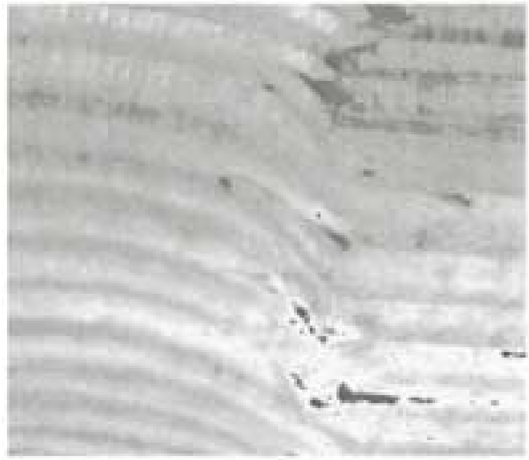


Photo 25. Failure of wood layers (8.75x).

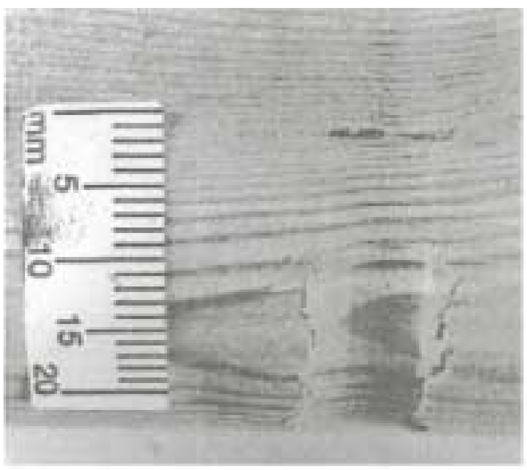


Photo 26. Opposite side, static fall indentation.

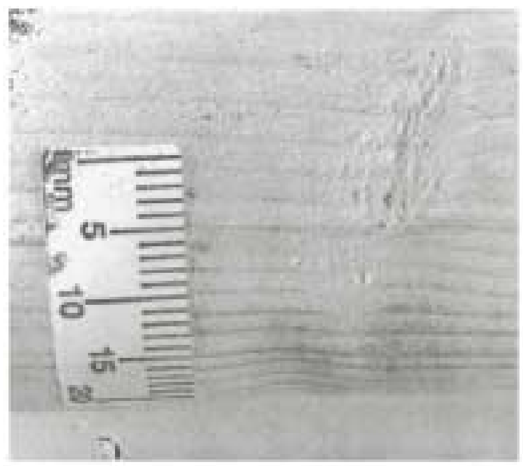


Photo 27. Ligature side, drag indentation.

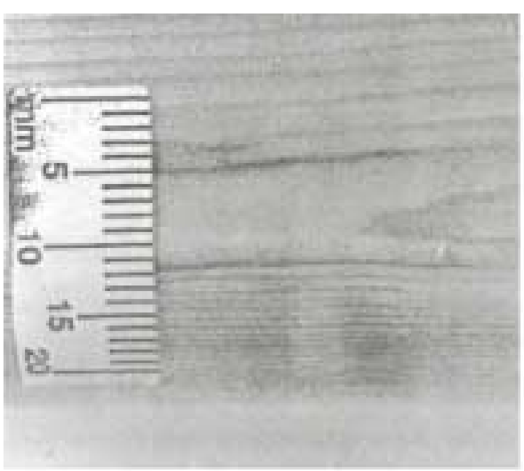


Photo 28. Ligature side, drag indentation.

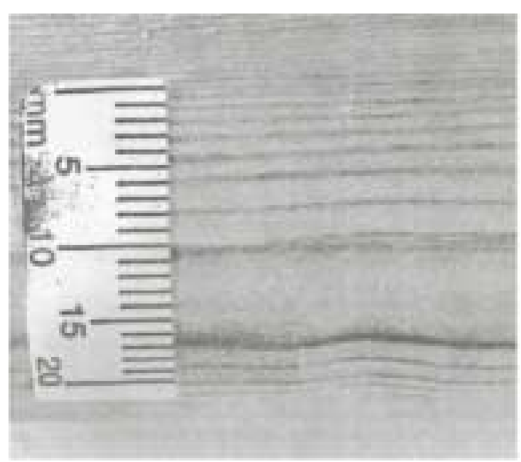


Photo 29. Opposite side, drag indentation.

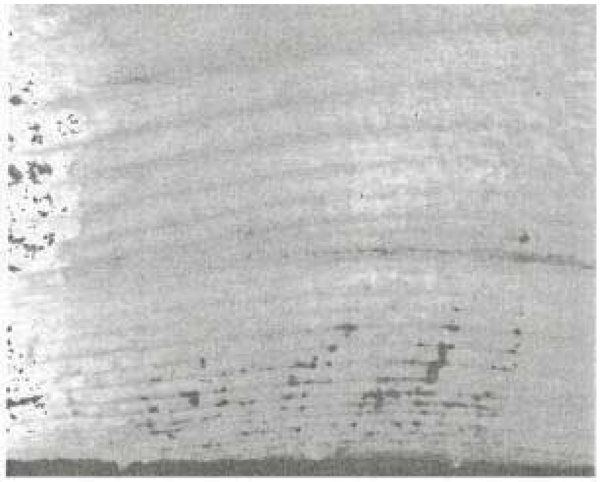


Photo 30. Drag trial indentation, minimal wood failure visible (8.75x).

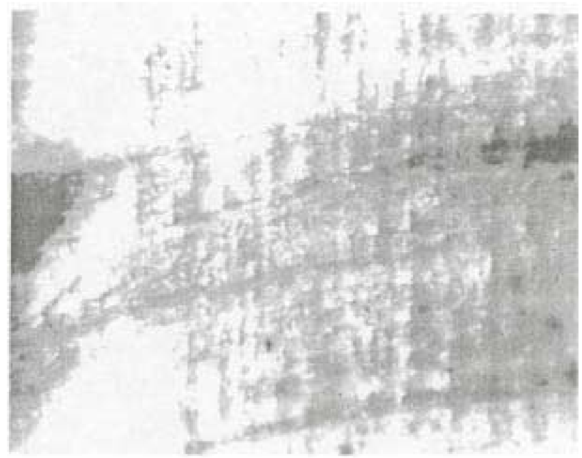


Photo 31. Striations evident, in static fall indentation (20x).

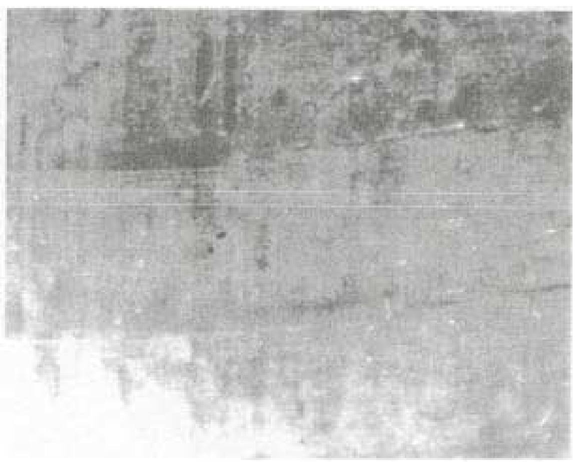


Photo 32. Striations evident, in drag trial indentation (20x).

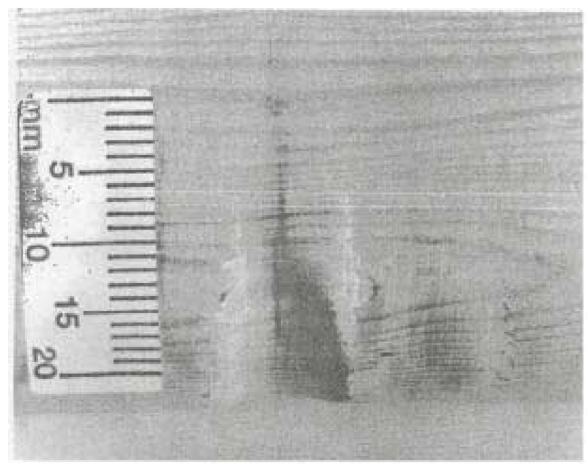


Photo 33. Double indentation evident in static fall trial, due to multiple loops of rope around the suspension beam.

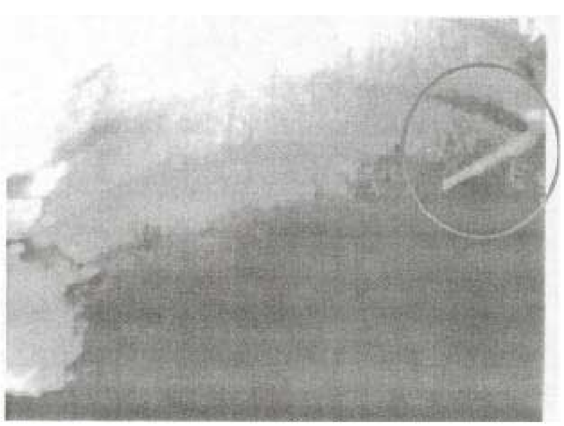


Photo 34. Ligature side, static fall indentation, example of wood splinter directed downwards (8.75x).

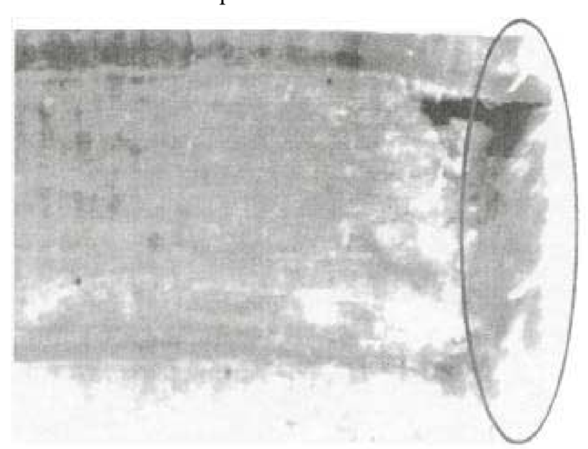


Photo 35. Ligature side, static fall indentation, example of fibres directed downwards (20x).

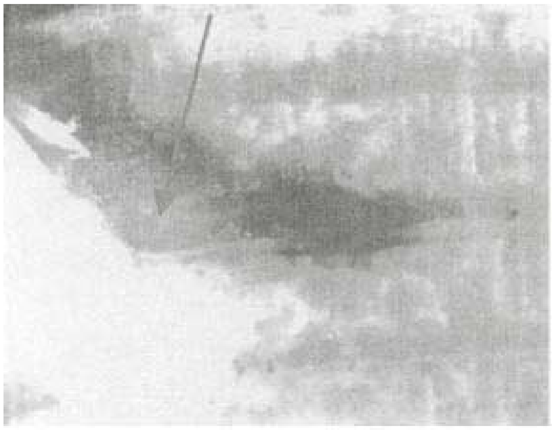


Photo 36. Ligature side, static fall indentation, wood splinter directed downwards (20x).

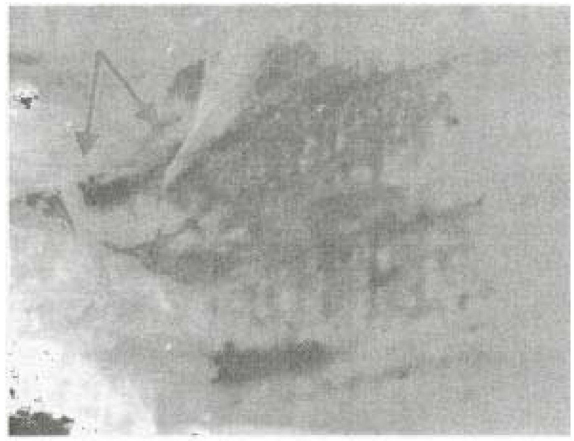


Photo 37. Ligature side, static fall indentation, wood splinters directed downwards (20x).

Photo 38. Example of wood splinter peeled back in direction of downward force, static fall trial (20x).

Photo 39. Another example of wood splinter in direction of downward force, static fall trial (20x).

Photo 40. Wood fibres directed downward, on the opposite side of static fall trial indentation (8.75x).

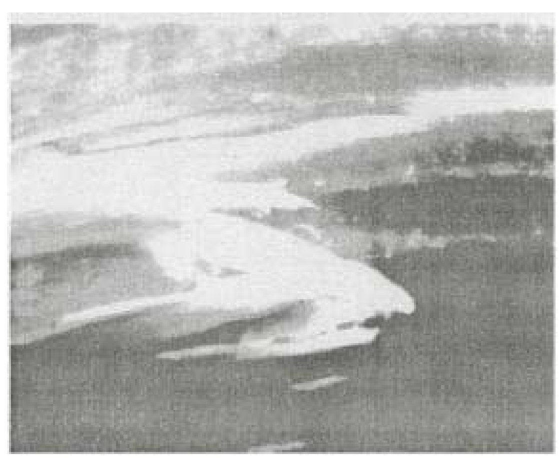


Photo 41. Wood fibres directed downward on the opposite side of static fall trial indentation

Photo 42. Wood fibre directed upwards, ligature side, drag trial (20x).

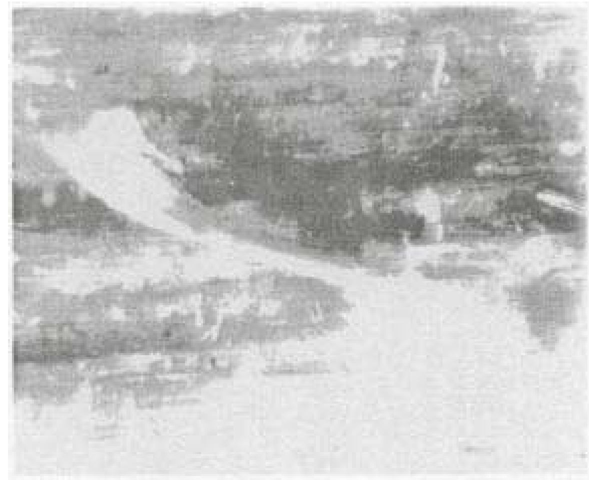


Photo 43. Wood fibres directed upwards, ligature side, drag trial (40x).

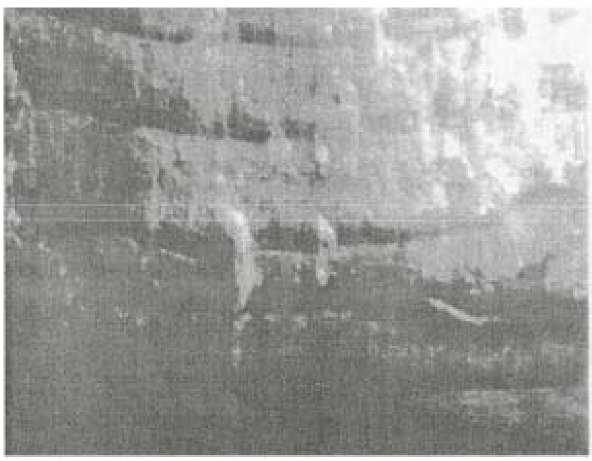


Photo 44. Wood fibres directed downwards, opposite side, drag trial (8.75x).

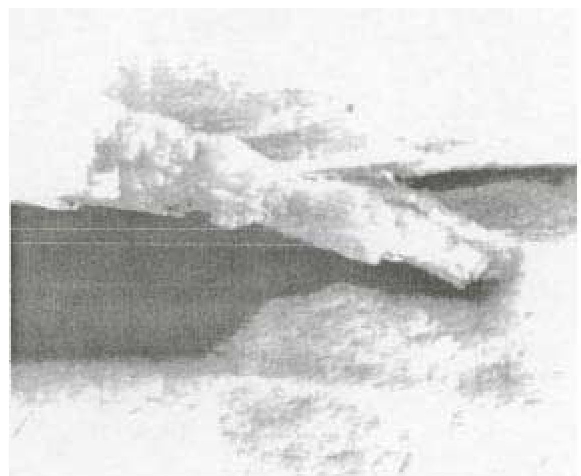


Photo 45. Wood splinter directed downwards, opposite side, drag trial (20x).

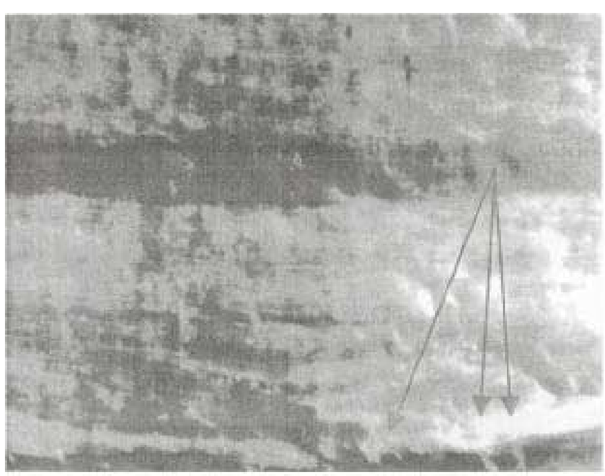


Photo 46. Wood fibres directed downwards, opposite side, drag trial

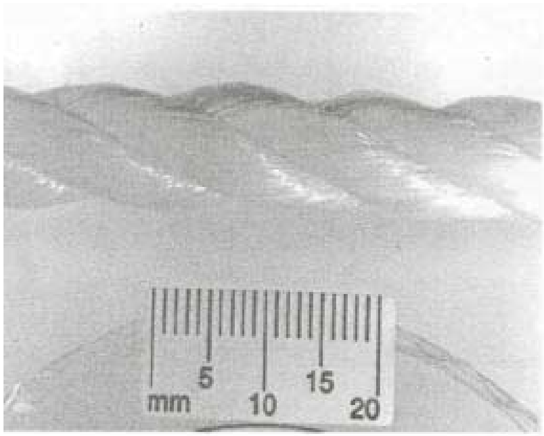


Photo 47. Control section of rope.

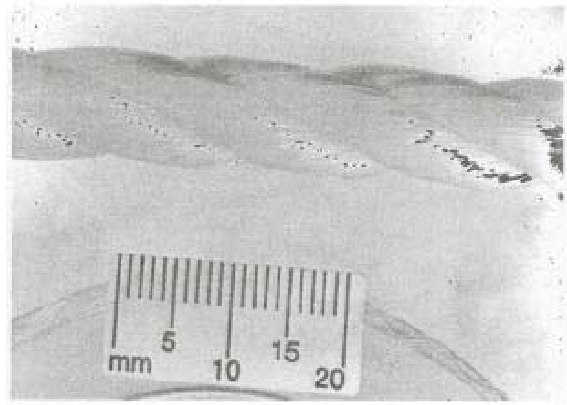


Photo 48. Control section of rope.

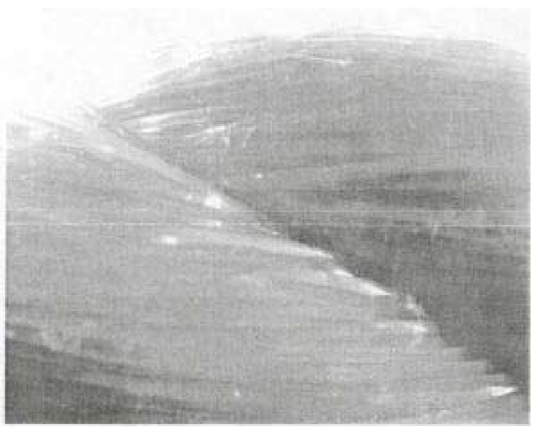


Photo 49. Control section of rope (8.75x).

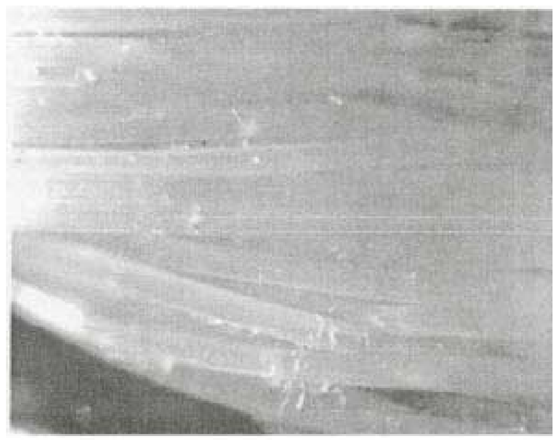


Photo 50. Control section of rope (20x).

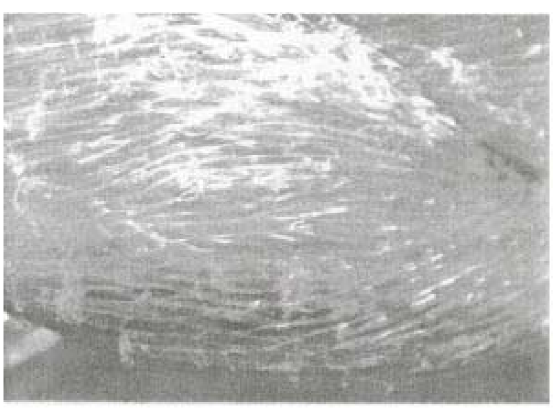


Photo 51. Compression area and filamentation of static fall trial rope, at first loop around suspension beam (8.75x).

Photo 52. Filamentation of static fall trial rope (20x).

Photo 53. Filamentation and flattened fibre of drag trial ligature rope (20x).

Photo 54. Filametation and flattened fibres of drag trial ligature rope (20x).

Photo 55. Filamentation of drag trial rope (40x).

Photo 56. Snag of individual rope fibre, pulled from the ligature during drag trial (8.75x).

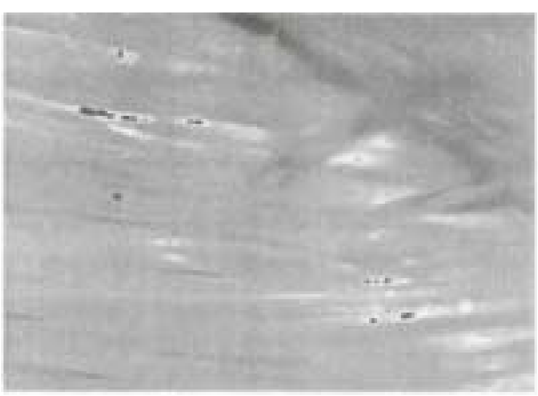


Photo 57. Close up of area where snag pulled from ligature (20x).

Photo 58. Example of rope fibre found within a drag indentation, rarely observed (20x).

APPENDIX C – TABLES 2 – 15

Summary Statistics of Area Measurements of Indentation Tapings

TABLE 2. Static Fall Trial Area Measurements

Board Number	Number of Trials	Mean Area (cm²)	Standard Deviation
Board 1	15	4.838	1.578
Board 2	15	3.290	0.877
Board 3	15	4.263	1.026
Board 4	15	5.083	0.957
Board 5	15	6.135	1.202
Board 6	15	4.354	0.668
Board 7	15	4.280	0.838
Board 8	9	4.853	0.567

TABLE 3. Drag Trial Area Measurements.

Board Number	Number of Trials	Mean Area (cm²)	Standard Deviation
Board 1	15	2.226	0.665
Board 2	15	1.8258	0.3692
Board 3	15	2.584	0.461
Board 4	15	2.685	0.412
Board 5	15	3.613	0.747
Board 6	15	3.452	0.708
Board 7	15	2.843	0.440
Board 8	9	2.988	0.606

Summary Statistics of Perimeter Measurements of Indentation Tapings

TABLE 4. Static Fall Trial Perimeter Measurements.

Board Number	Number of Trials	Mean Perimeter(cm)	Standard Deviation
Board 1	15	11.366	2.081
Board 2	15	9.864	1.313
Board 3	15	9.524	1.824
Board 4	15	10.860	2.857
Board 5	15	13.180	1.132
Board 6	15	10.608	0.902
Board 7	15	10.794	1.148
Board 8	9	11.686	0.734

TABLE 5. Drag Trial Perimeter Measurements.

Board Number	Number of Trials	Mean Perimeter(cm)	Standard Deviation
Board 1	15	7.205	1.076
Board 2	15	6.436	1.601
Board 3	15	7.152	0.735
Board 4	15	7.196	0.700
Board 5	15	8.884	1.011
Board 6	15	8.647	1.489
Board 7	15	7.710	0.675
Board 8	9	7.940	0.636

Summary Statistics of Control Board Initial Measurements

TABLE 6. Ligature Side Control Measurements.

Board Number	Number of Measurements	Mean Initial Depth (mm)	Standard Deviation
Board 1	15	6.1360	0.1853
Board 2	15	6.1113	0.2095
Board 3	15	5.9453	0.0777
Board 4	15	5.5393	0.2175
Board 5	15	6.0933	0.2074
Board 6	15	6.7253	0.1104
Board 7	15	6.3560	0.1416
Board 8	15	6.0813	0.1756

TABLE 7. Opposite Side Control Measurements.

	Number of Measurements	Mean Initial Depth (mm)	Standard Deviation
Board 1	15	6.2747	0.1429
Board 2	15	5.7833	0.1699
Board 3	15	6.1007	0.2056
Board 4	15	5.5587	0.1523
Board 5	15	6.1907	0.1104
Board 6	15	6.5520	0.1242
Board 7	15	6.4720	0.1599
Board 8	15	6.0867	0.1716

Board Indentation Depth Measurements*

(*after subtraction of Initial Control measurements and recalculation of combined Standard Deviation)

TABLE 8. Ligature Side Indentation Depth Measurements – Static Fall Trials.

Board Number	Indentation Depth (mm)	Standard Deviation
Board 1	2.9003	0.1047
Board 2	2.2913	0.0936
Board 3	2.4278	0.0744
Board 4	3.4205	0.1073
Board 5	4.2817	0.1133
Board 6	1.4674	0.0660
Board 7	3.3453	0.0749
Board 8	3.5477	0.1211

TABLE 9. Opposite Side Indentation Depth Measurements – Static Fall Trials.

Board Number	Indentation Depth (mm)	Standard Deviation
Board 1	0.9917	0.0626
Board 2	1.8768	0.0740
Board 3	1.5113	0.0661
Board 4	3.0103	0.1149
Board 5	2.4015	0.0058
Board 6	1.5200	0.0604
Board 7	2.2704	0.0889
Board 8	3.0383	0.1268

TABLE 10. Ligature Side Indentation Depth Measurements – Drag Trials.

Board Number	Indentation Depth (mm)	Standard Deviation
Board 1	0.4620	0.0674
Board 2	0.7636	0.0625
Board 3	0.6767	0.0277
Board 4	1.0431	0.0643
Board 5	1.0543	0.0681
Board 6	0.8863	0.0402
Board 7	1.1322	0.0564
Board 8	1.0087	0.0574

TABLE 11. Opposite Side Indentation Depth Measurements – Drag Trials.

Board Number	Indentation Depth (mm)	Standard Deviation
Board 1	0.2117	0.0607
Board 2	0.7835	0.0415
Board 3	0.9969	0.0591
Board 4	1.9777	0.0954
Board 5	1.0662	0.0446
Board 6	1.0789	0.0406
Board 7	1.2618	0.0531
Board 8	1.3058	0.1014

Summary Statistics of Indentation Measurements for Static Fall and Drag Trials

TABLE 12. Ligature Side Indentation Depth Measurements – Static Fall Trials.

Board Number	Number of Measurements	Mean Indentation Depth (mm)	Standard Deviation
Board 1	30	9.0363	0.5102
Board 2	39	8.4026	0.4767
Board 3	45	8.3731	0.4804
Board 4	45	8.9598	0.6135
Board 5	45	10.375	0.6700
Board 6	45	8.1927	0.3991
Board 7	45	9.7013	0.4383
Board 8	24	9.6290	0.5500

TABLE 13. Opposite Side Indentation Depth Measurements – Static Fall Trials.

Board Number	Number of Measurements	Indentation Depth (mm)	Standard Deviation
Board 1	30	6.7750	0.2448
Board 2	39	8.1515	0.4008
Board 3	45	7.6120	0.2639
Board 4	45	8.5690	0.7240
Board 5	45	8.5922	0.3215
Board 6	45	8.0720	0.3430
Board 7	45	8.7424	0.5284
Board 8	24	9.1250	0.5820

TABLE 14. Ligature Side Indentation Depth Measurements – Drag Trials.

Board Number	Number of Measurements	Indentation Depth (mm)	Standard Deviation
Board 1	30	6.5980	0.2599
Board 2	39	6.8749	0.2105
Board 3	45	6.6220	0.1284
Board 4	45	6.5824	0.2097
Board 5	45	7.1476	0.2821
Board 6	45	7.6116	0.1906
Board 7	45	7.4882	0.2877
Board 8	24	7.0900	0.1723

TABLE 15. Opposite Side Indentation Depth Measurements – Drag Trials.

Board Number	Number of Measurements	Indentation Depth (mm)	Standard Deviation
Board 1	30	5.9950	0.2297
Board 2	39	7.0582	0.1270
Board 3	45	7.0976	0.1746
Board 4	45	7.5364	0.5832
Board 5	45	7.2569	0.2304
Board 6	45	7.6309	0.1671
Board 7	45	7.7338	0.2240
Board 8	24	7.3925	0.4466

APPENDIX D – CHARTS 1 – 40

Chart 1. Mean Area Measurements of Static Fall Trial Indentation Tapings for all Boards.

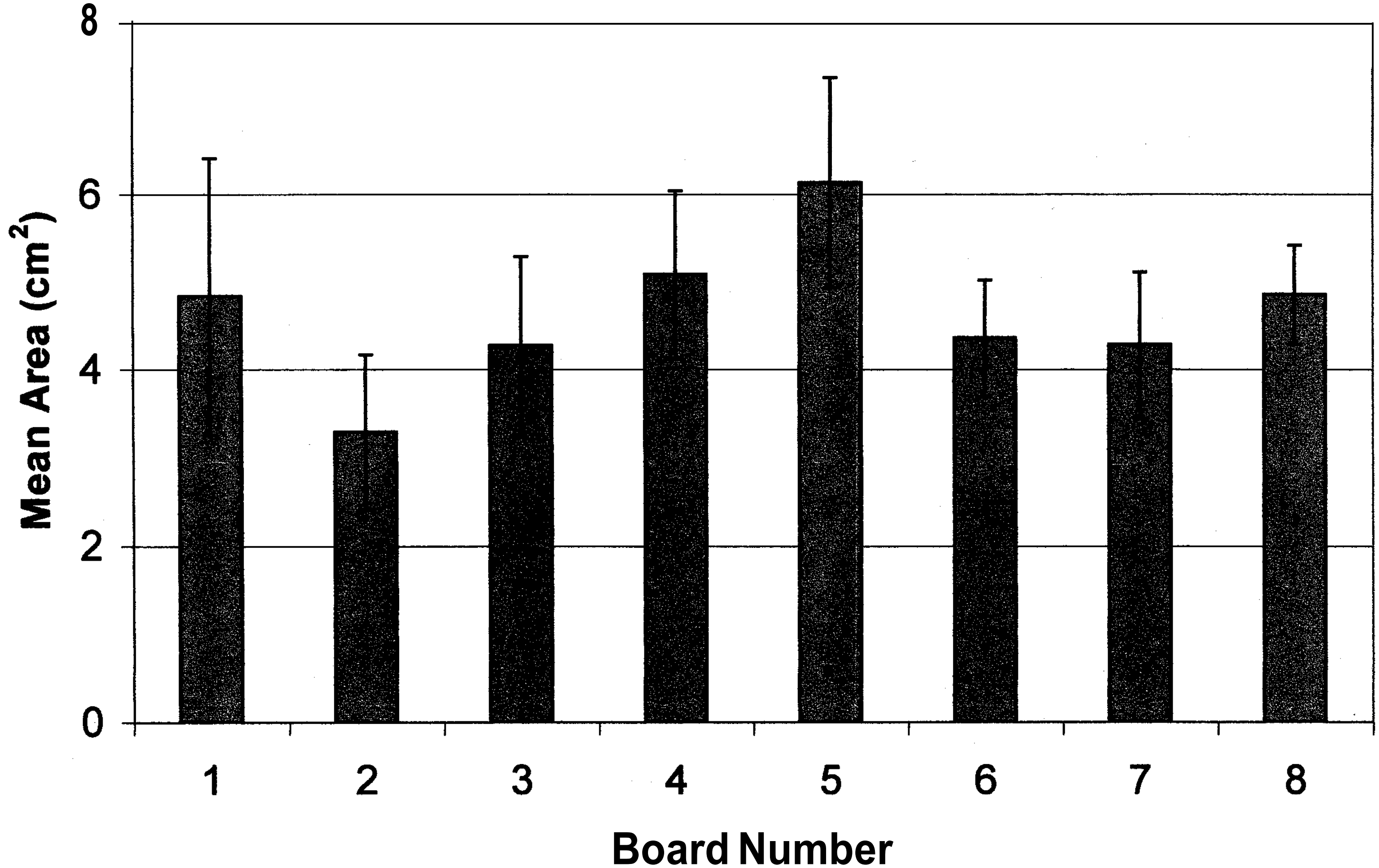


Chart 2. Mean Area Measurements of Drag Trial Indentation Tapings for all Boards.

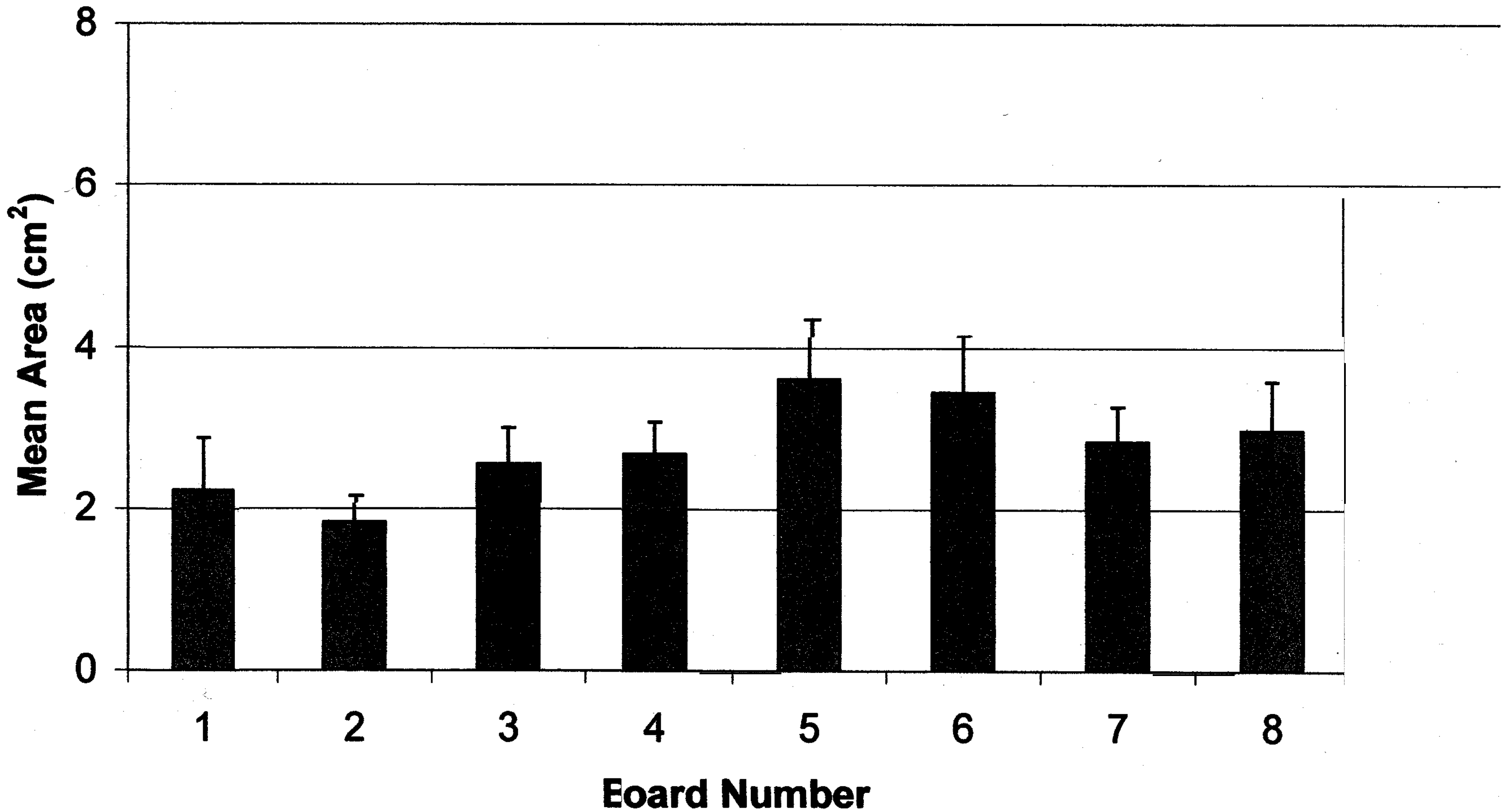


Chart 3. Mean Area Measurements of Board 1 Static Fall and Drag Indentation Tapings.

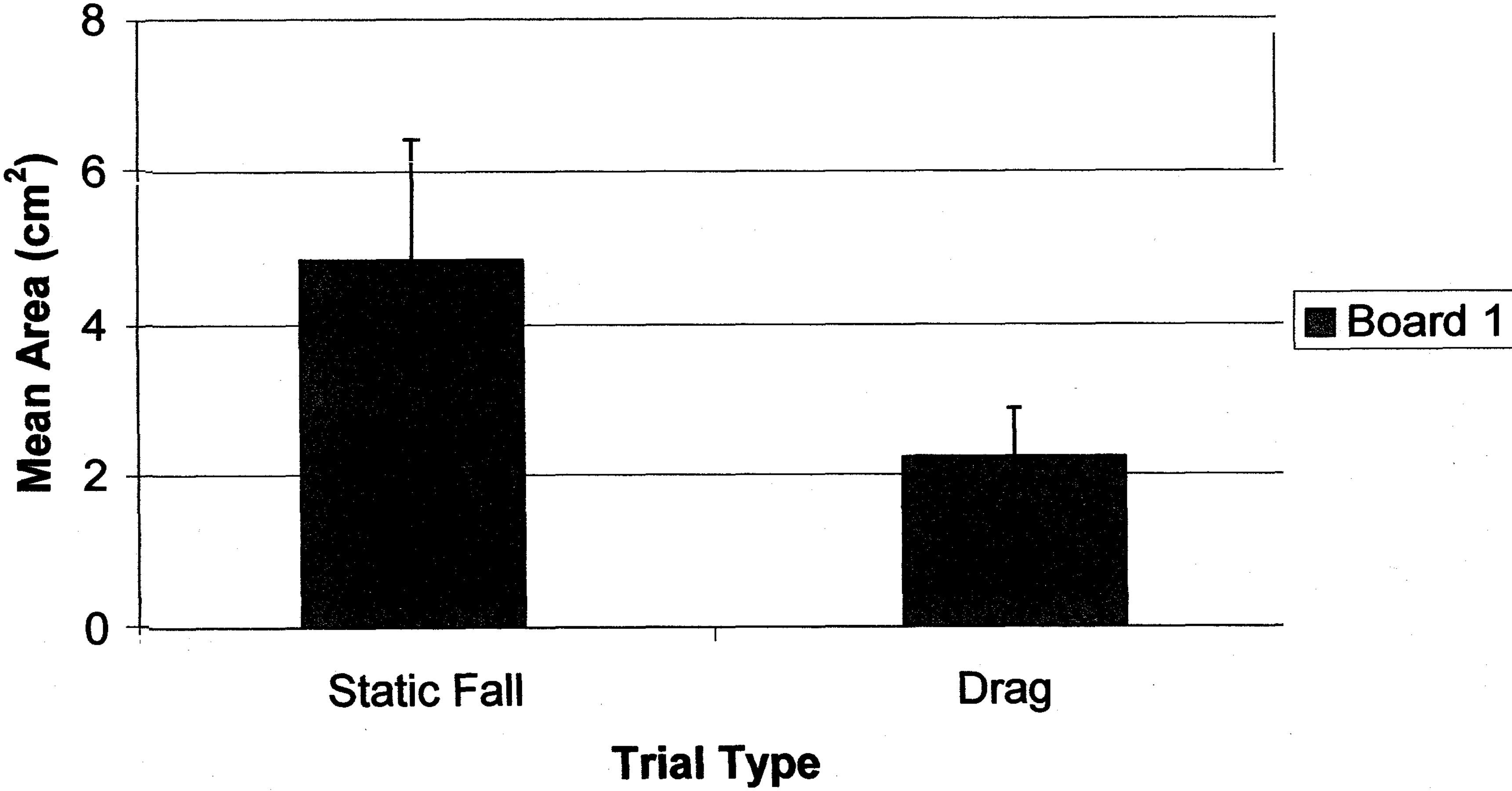


Chart 4. Mean Area Measurements of Board 2
Static Fall and Drag Indentation Tapings.

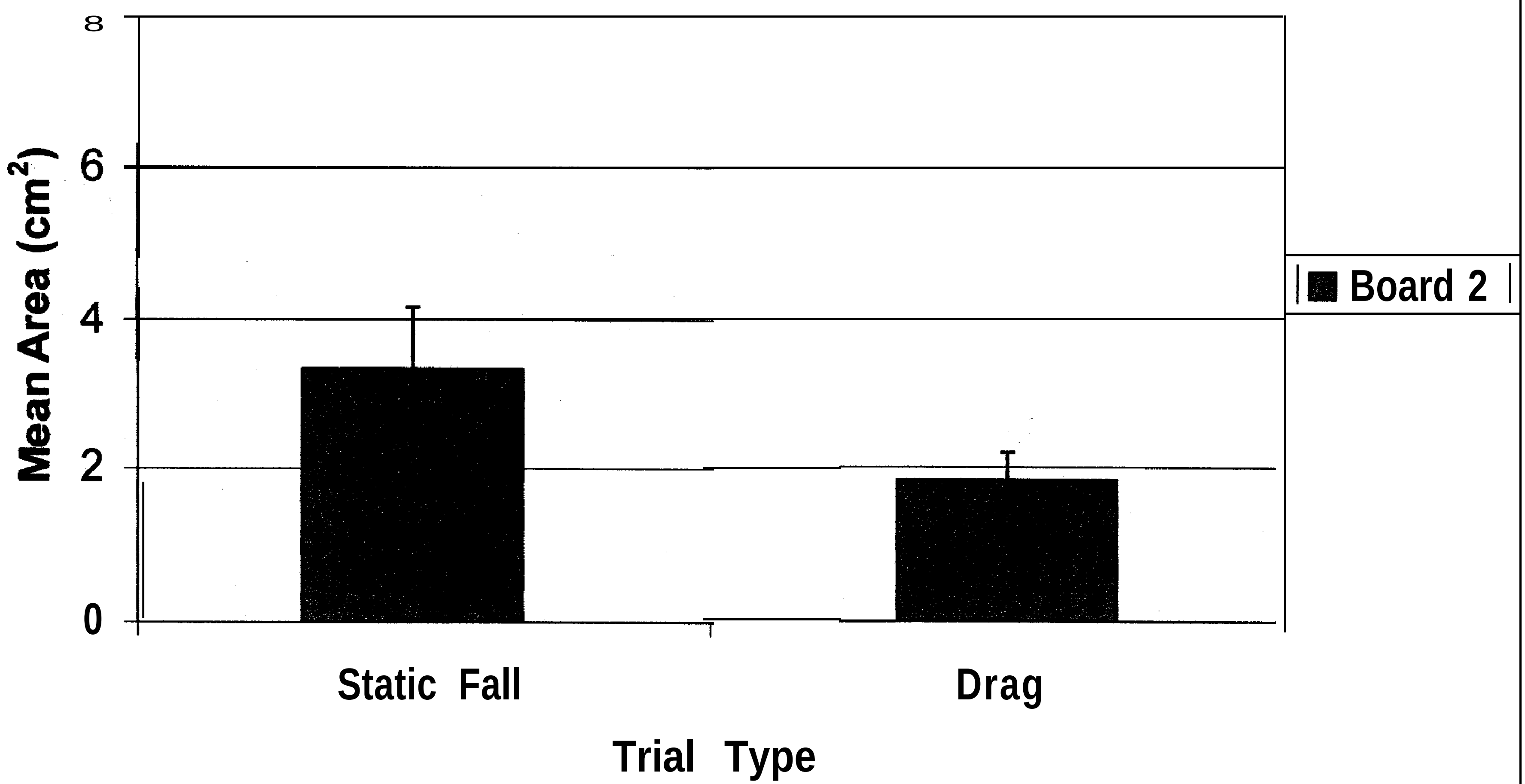


Chart 5. Mean Area Measurements of Board 3 Static Fall and Drag Indentation Tapings.

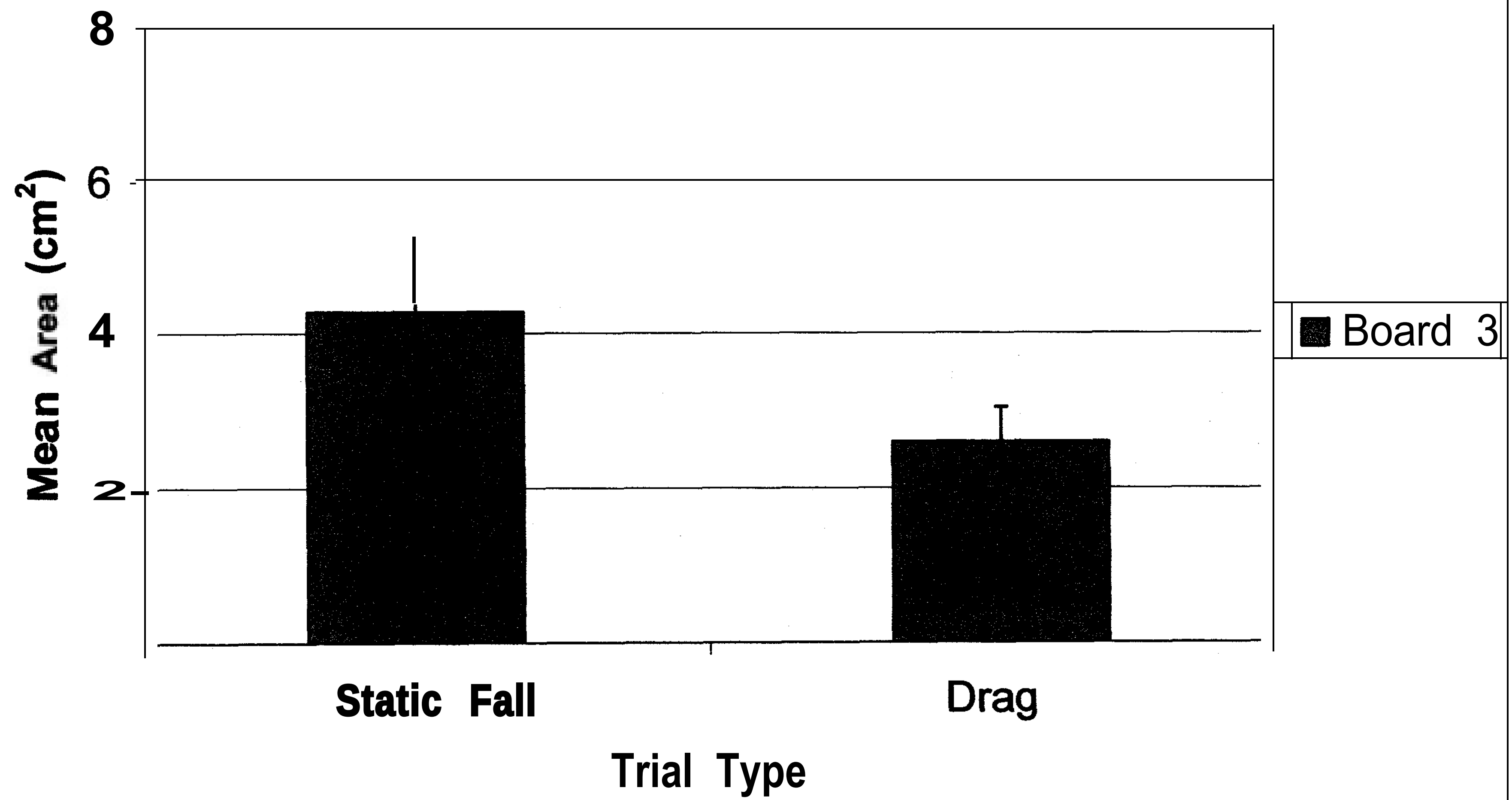


Chart 6. Mean Area Measurements of Board 4 Static Fall and Drag Indentation Tapings.

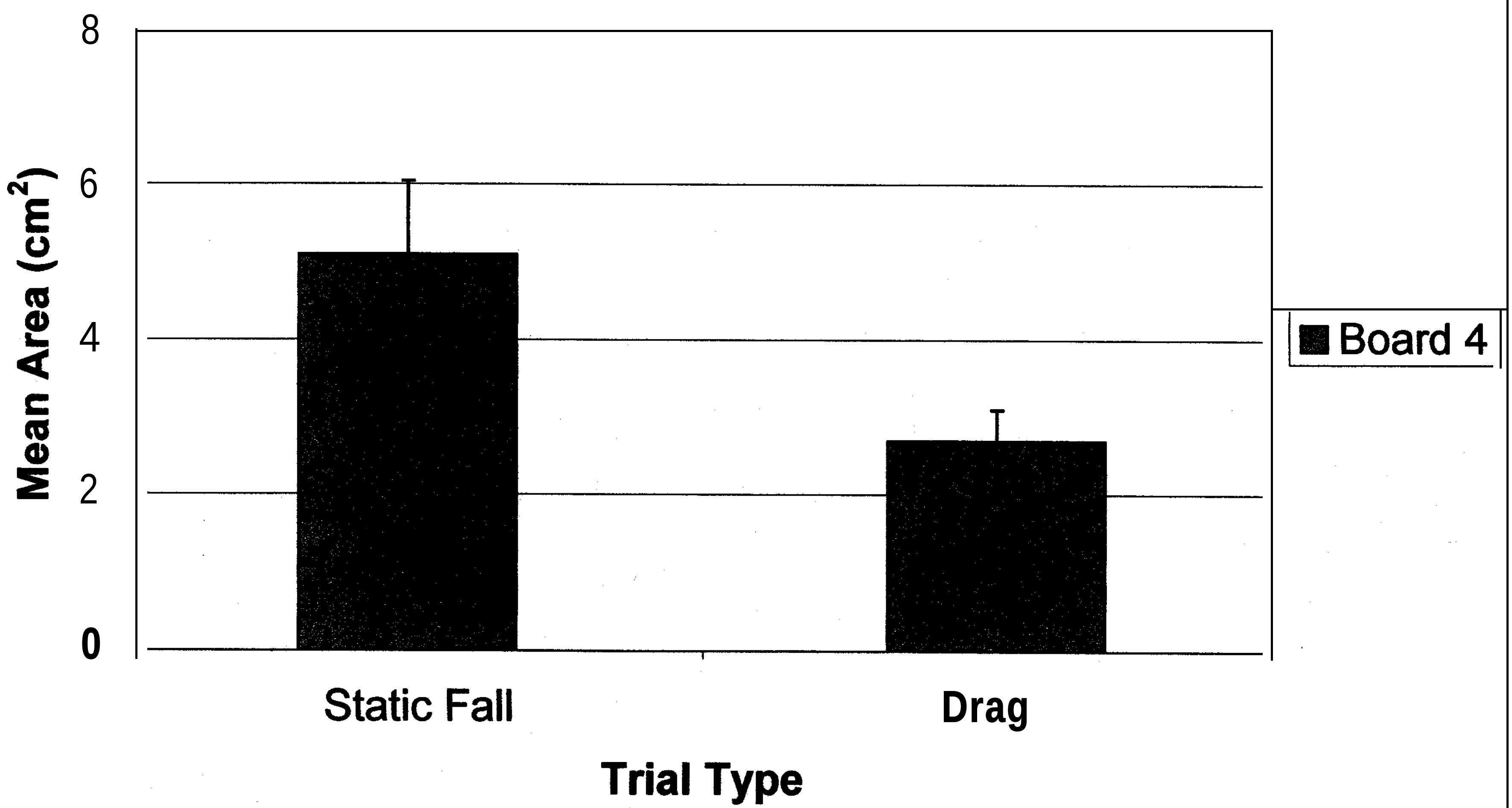


Chart 7. Mean Area Measurements of Board 5 Static Fall and Drag Indentation Tapings.

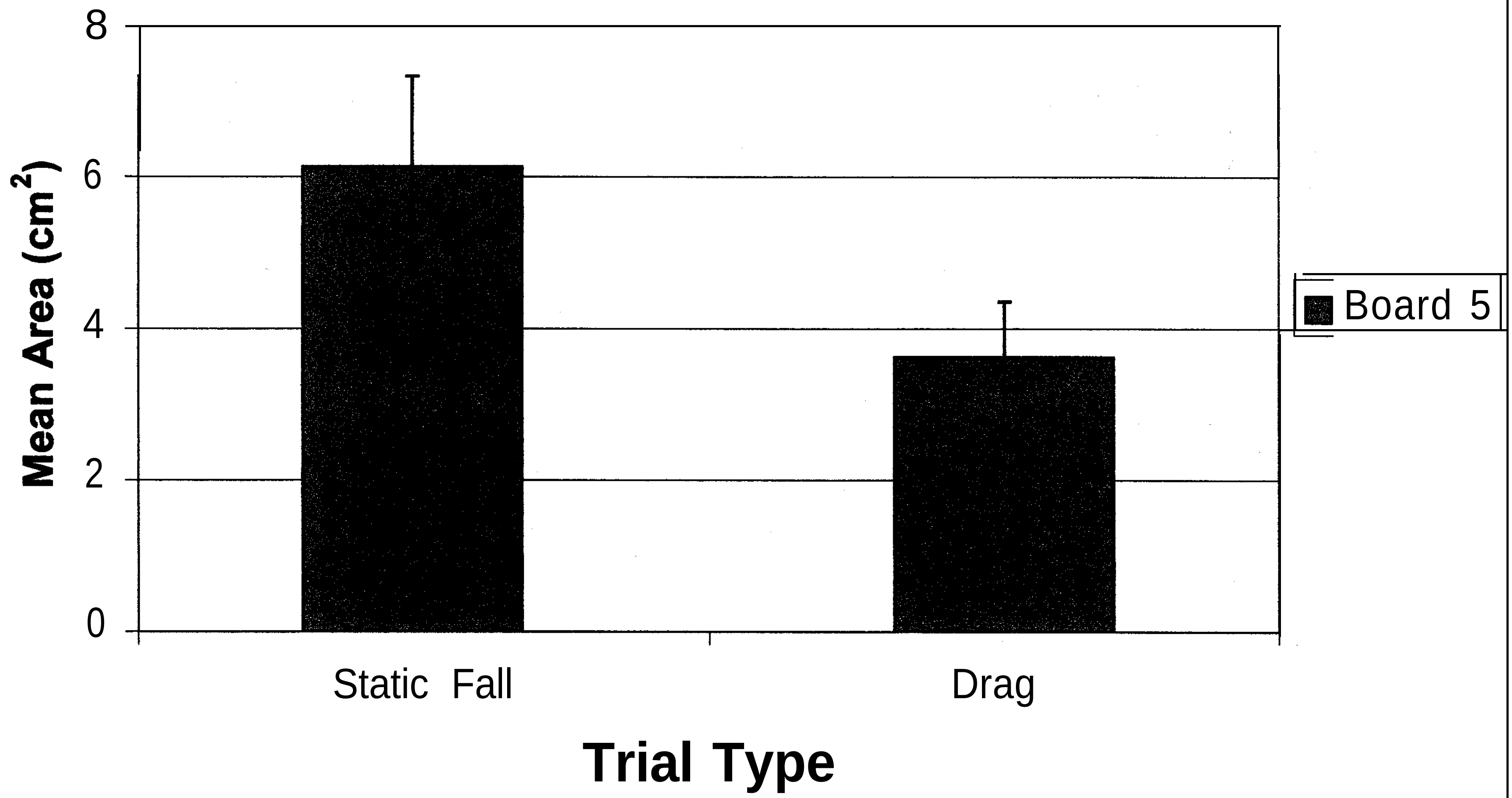


Chart 8. Mean Area Measurements. of Board 6 Static Fall and Drag Indentation Tapings.

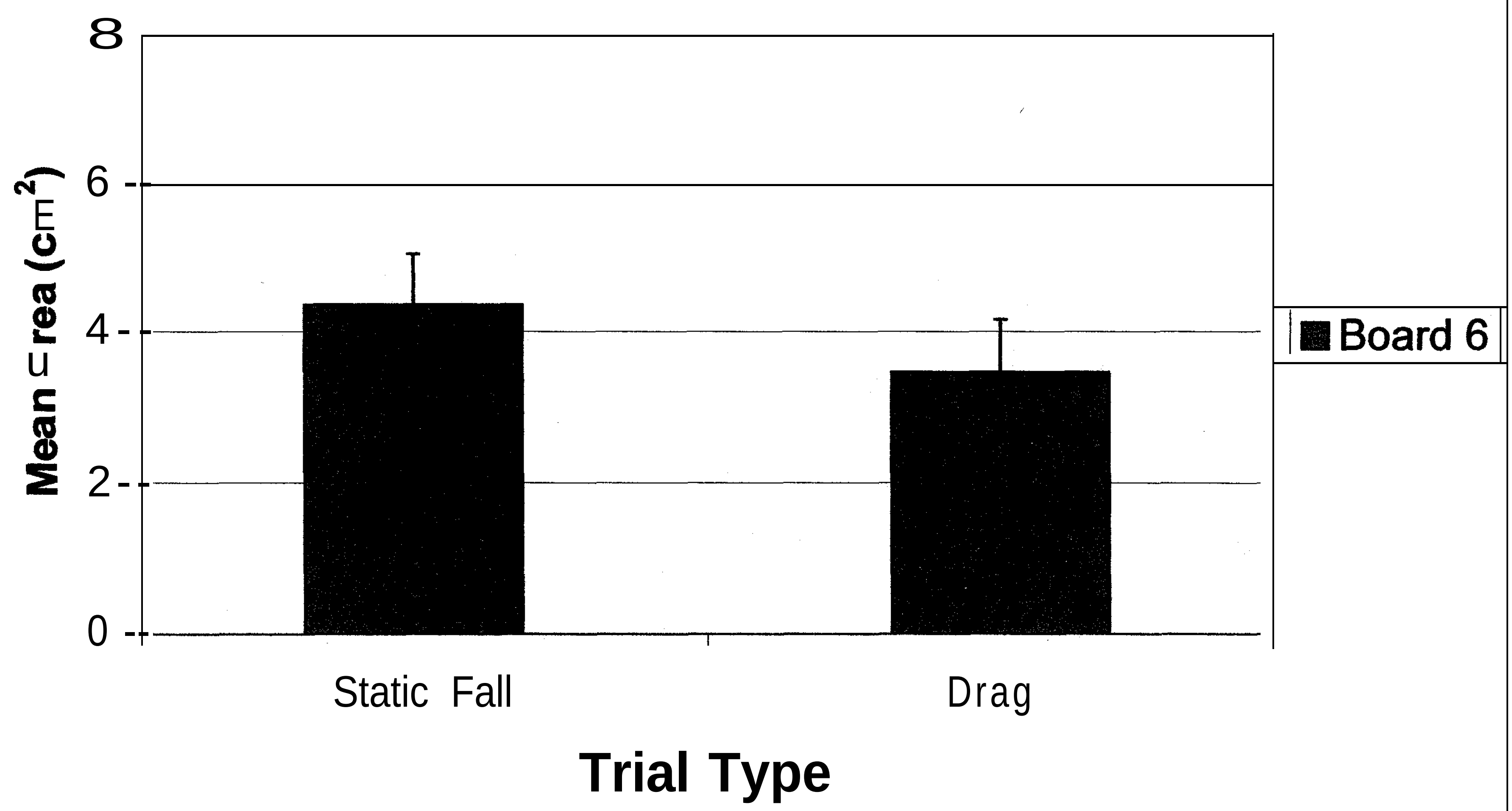


Chart 9. Mean Area Measurements of Board 7 Static Fall and Drag Indentation Tapings.

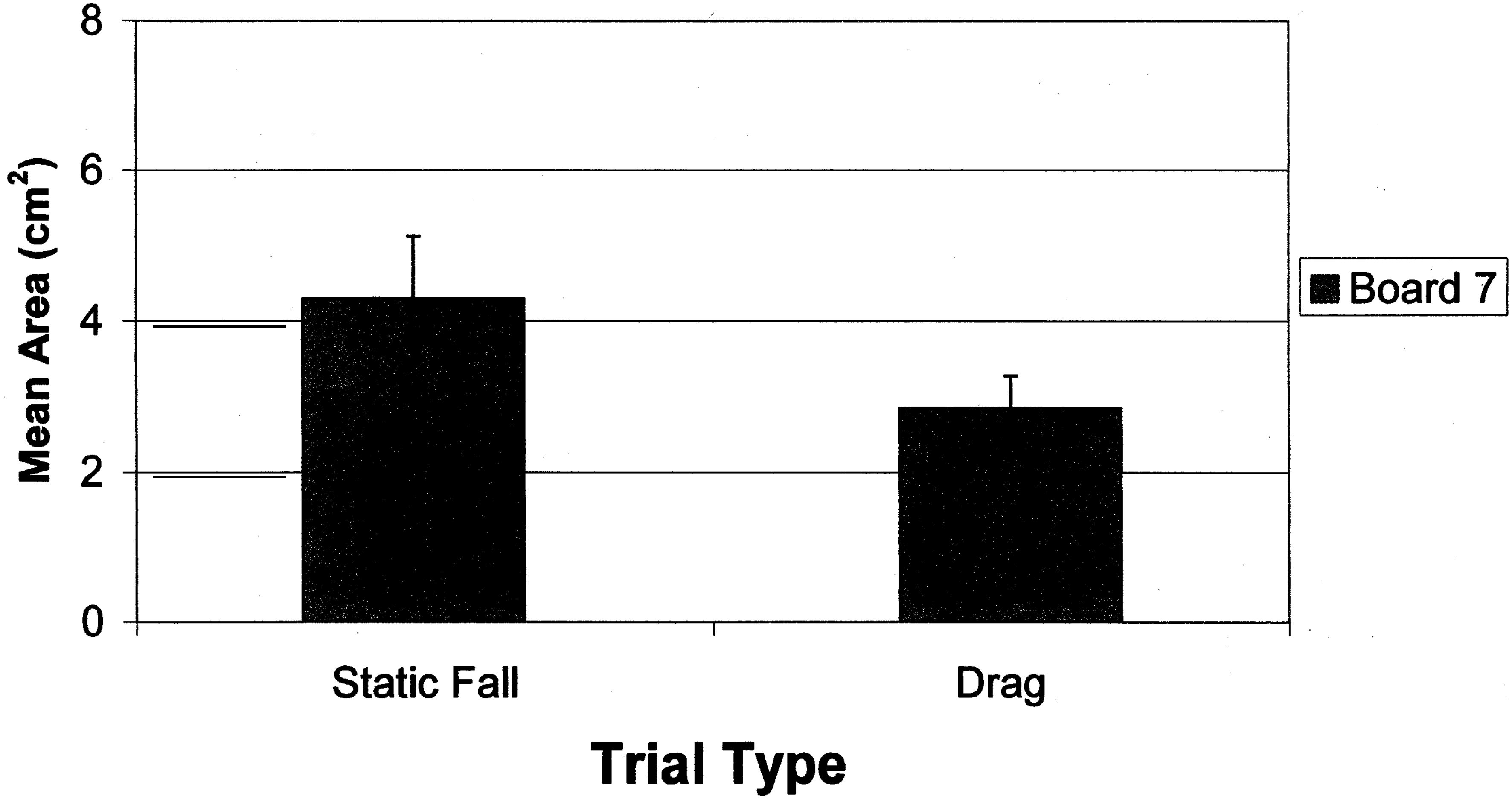


Chart 10. Mean Area Measurements of Board 8 Static Fall and Drag Indentation Tapings.

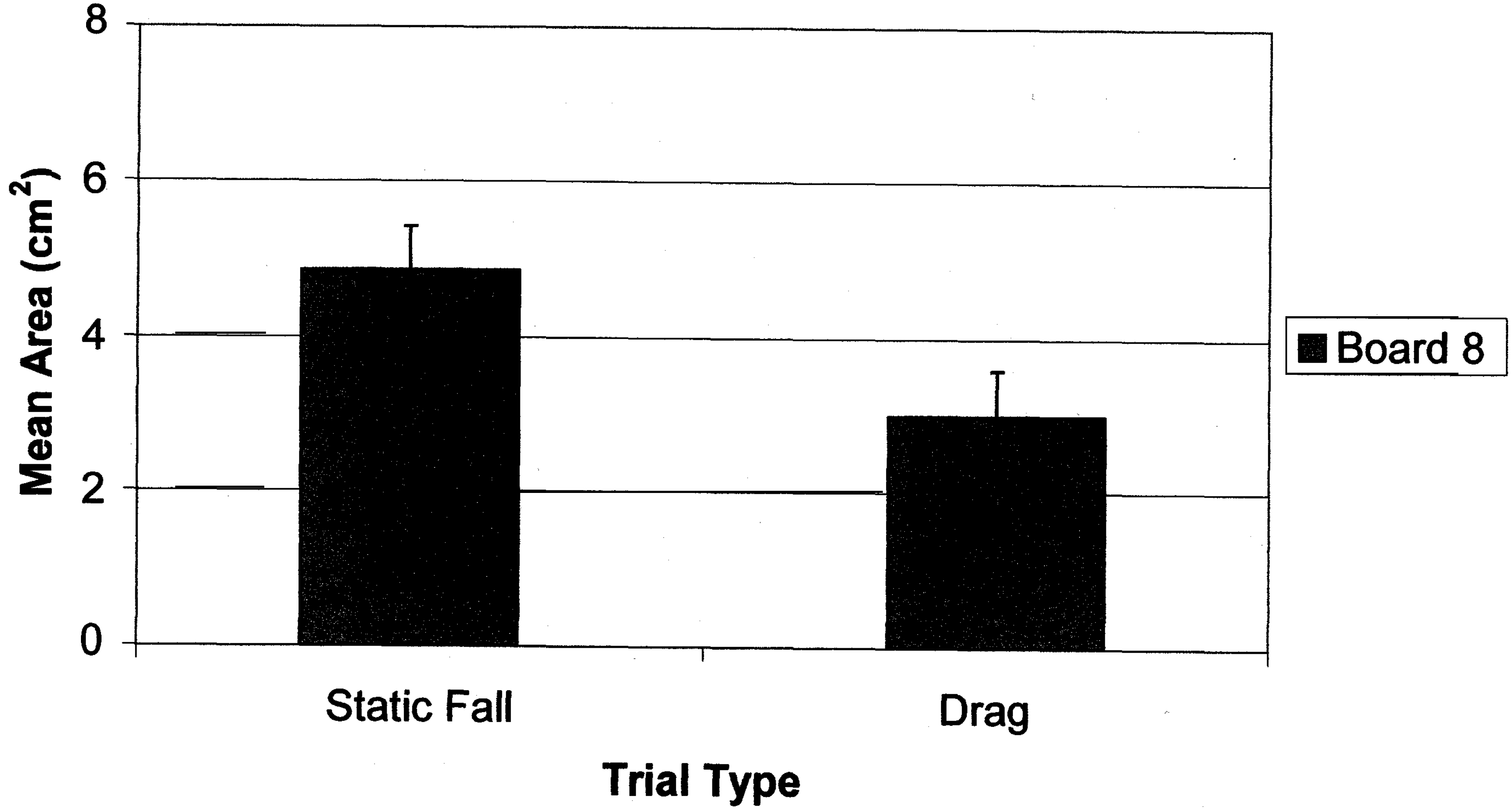


Chart 11. Mean Perimeter Measurements of Static Fall Trial Indentation Tapings for all Boards.

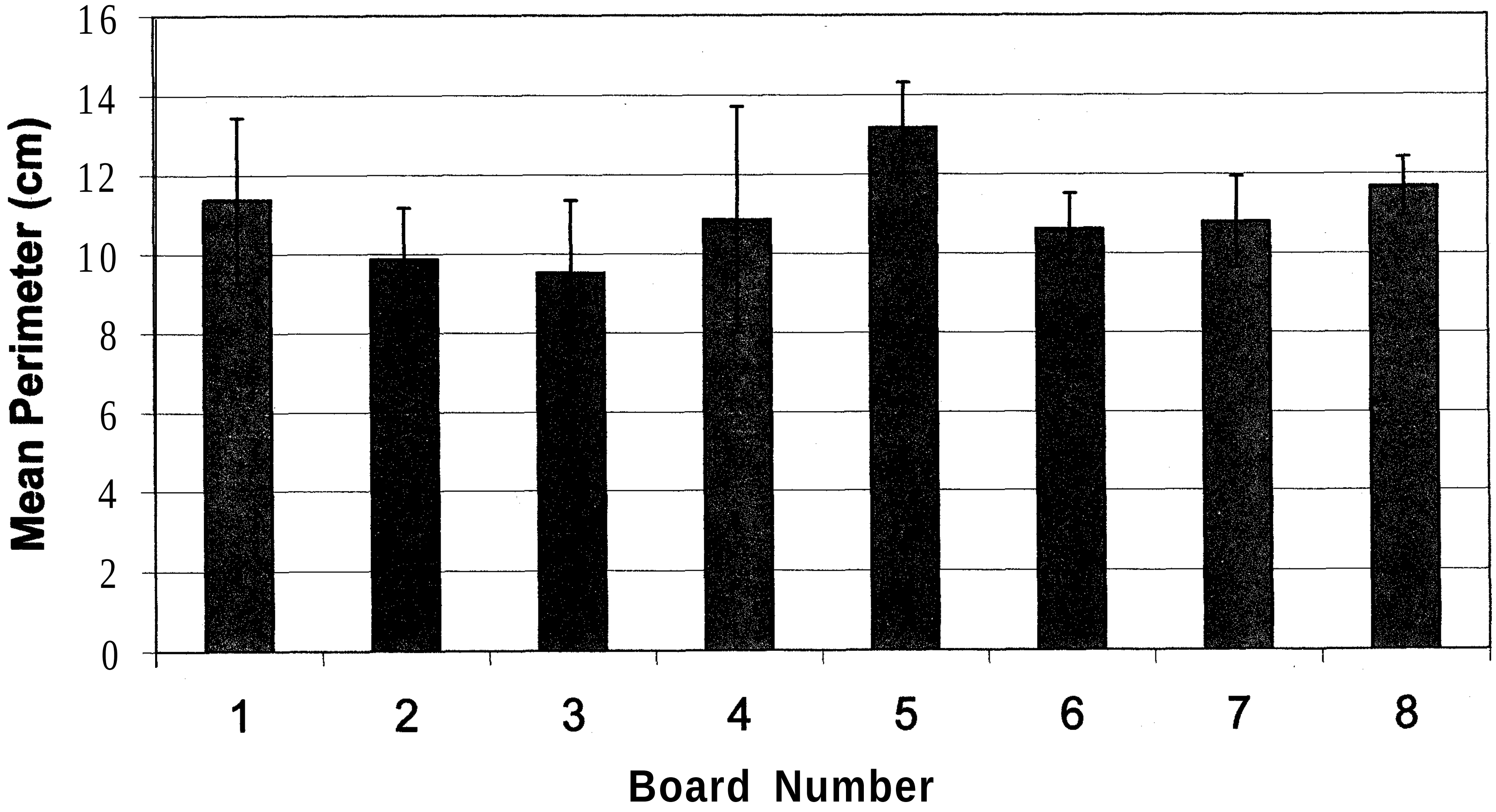


Chart 12. Mean Perimeter Measurements of Static Fall Trial Indentation Tapings for all Boards.

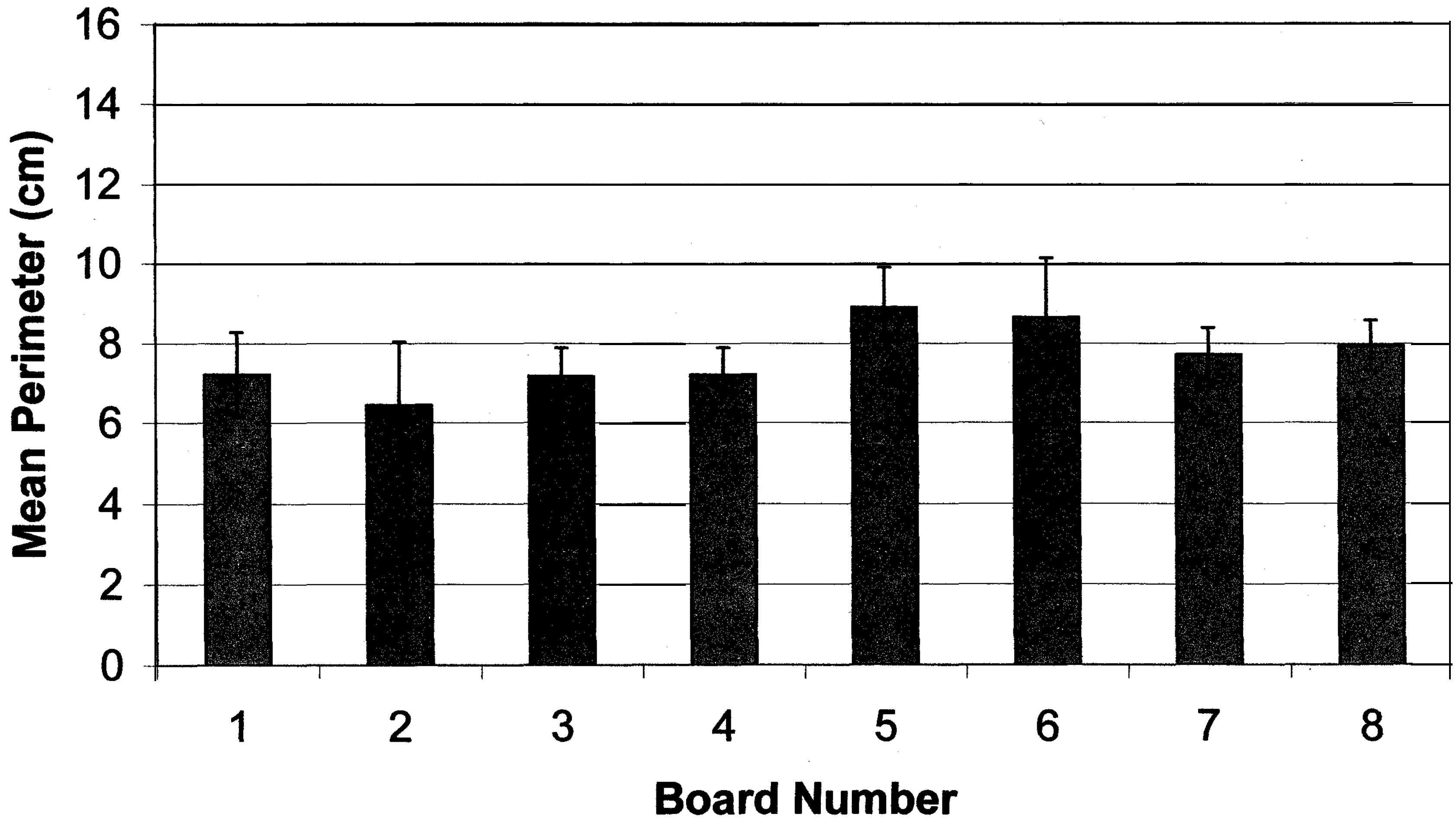


Chart 13. Mean Perimeter Measurements of Board 1 Static Fall and Drag Indentation Tapings

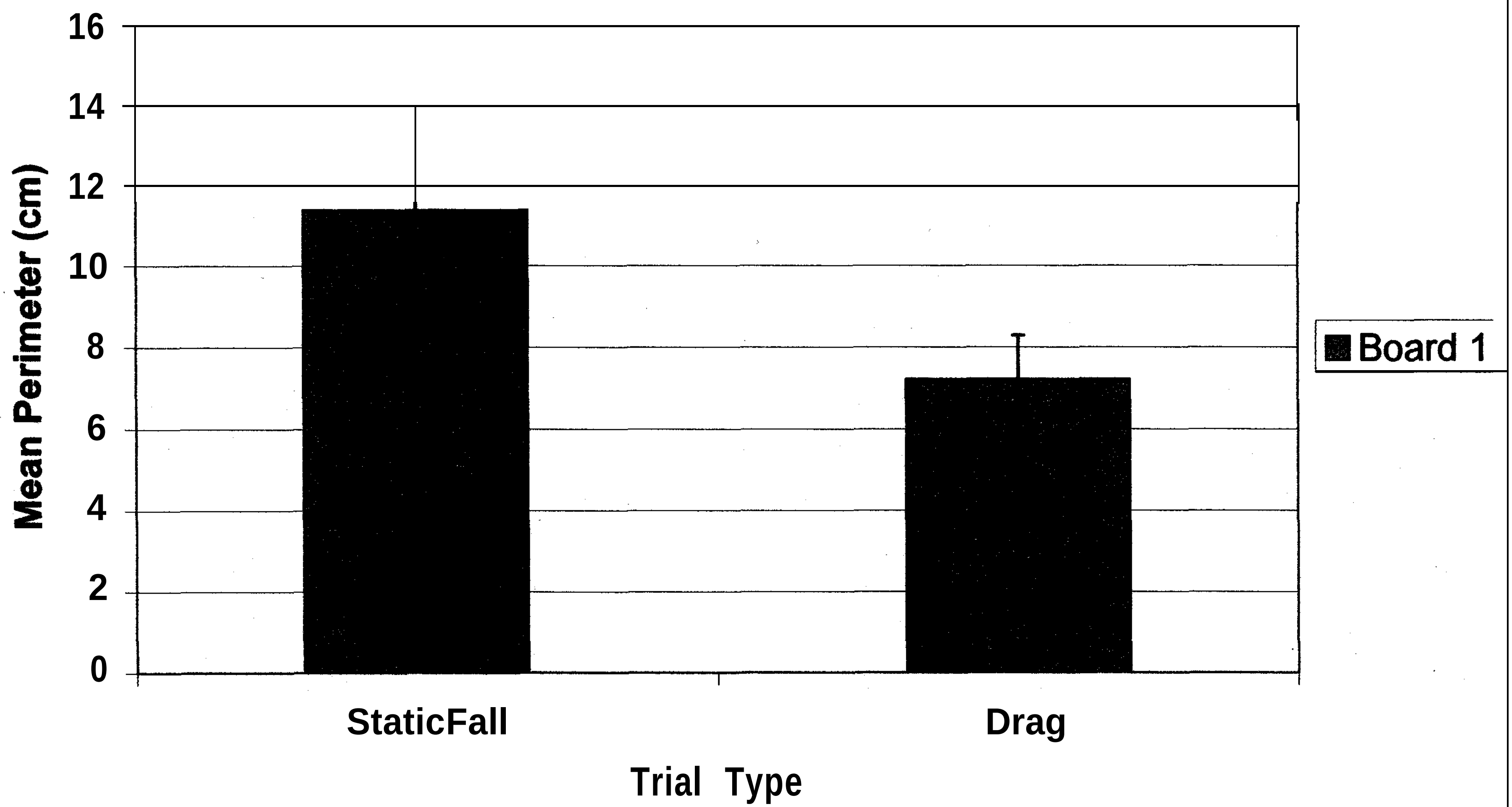


Chart 14. Mean Perimeter Measurements of Board 2 Static Fall and Drag Indentation Tapings

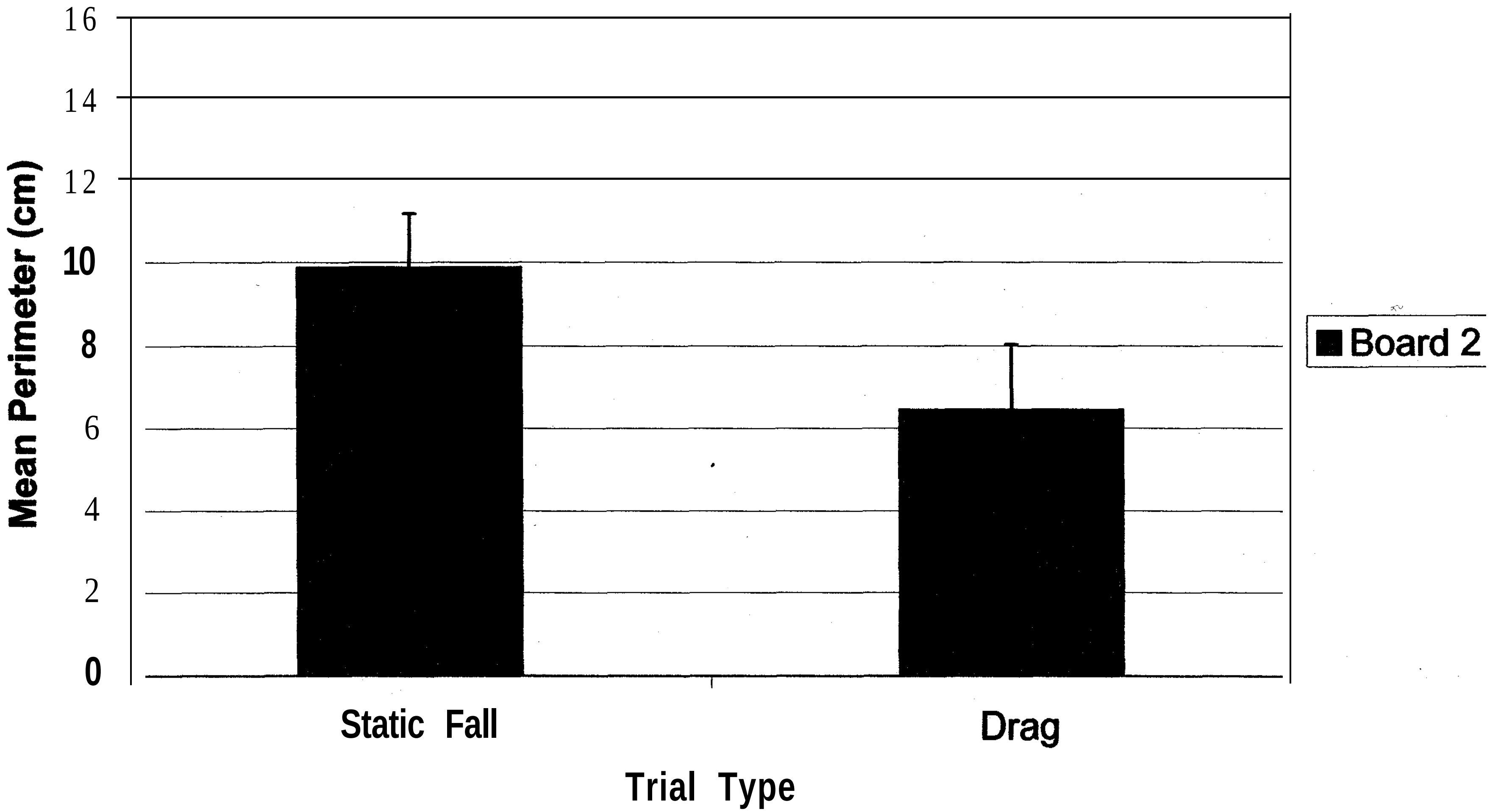


Chart 15. Mean Perimeter Measurements of Board 3 Static Fall and Drag Indentation Tapings

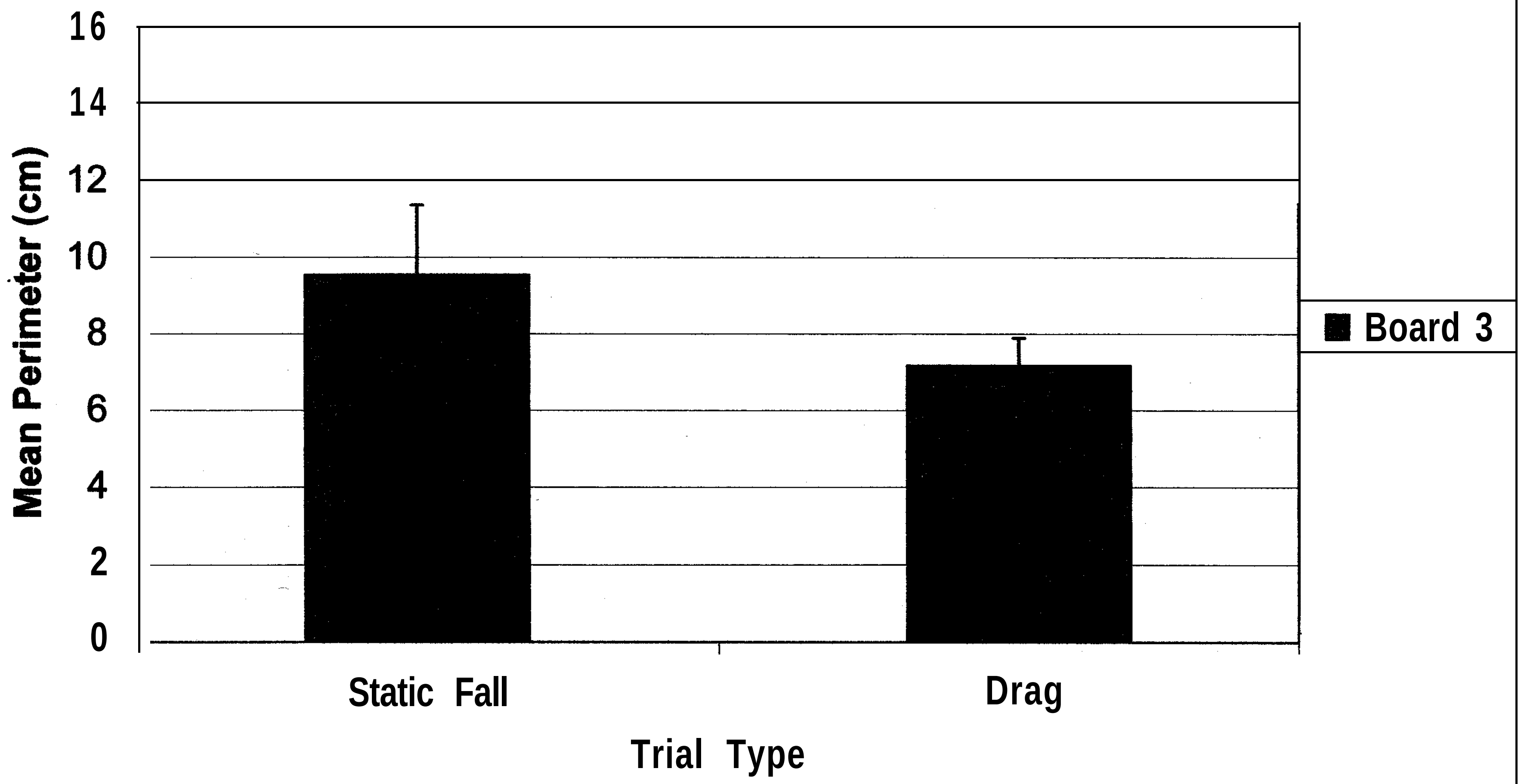


Chart 16. Mean Perimeter Measurements of Board 4 Static Fall and Drag Indentation Tapings

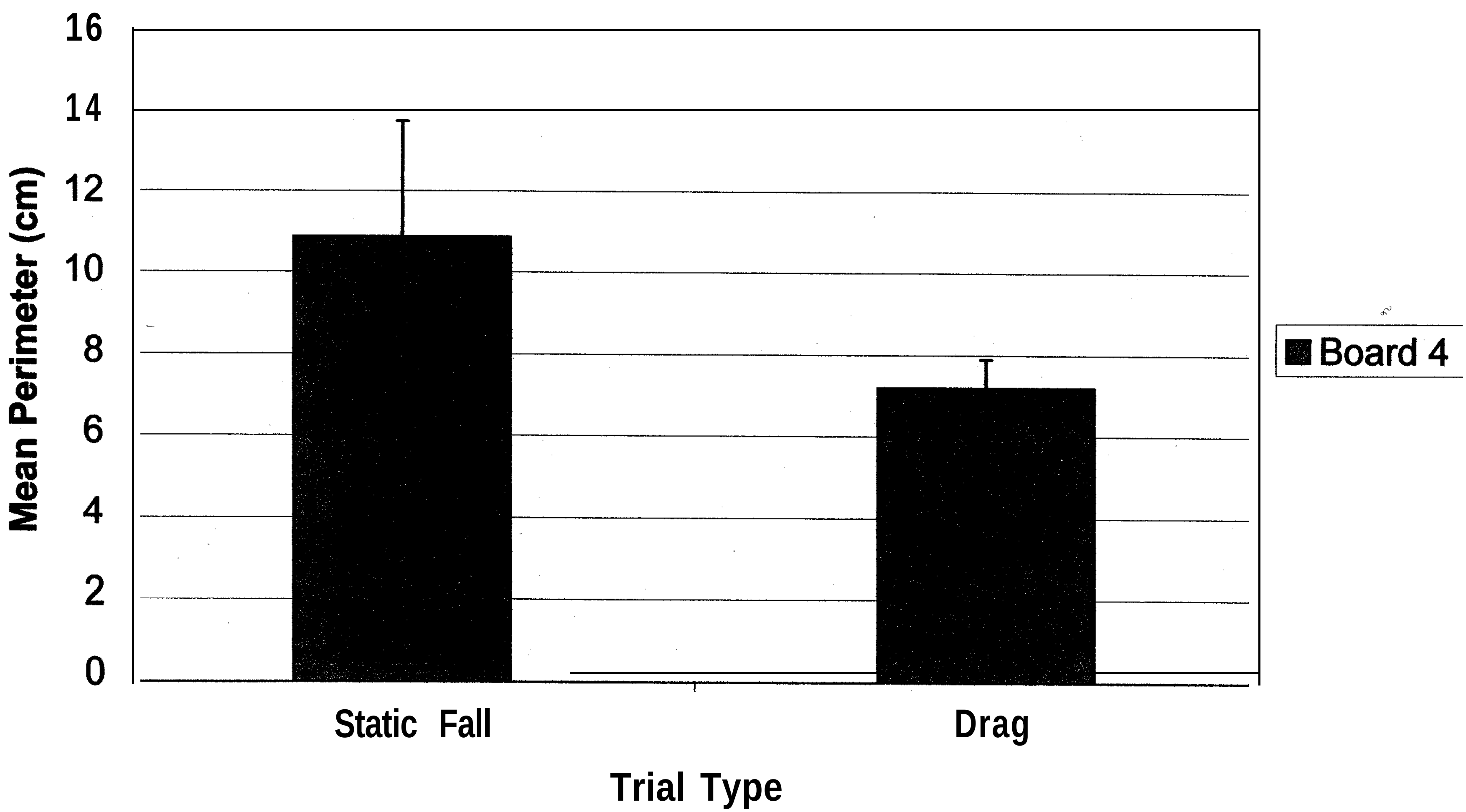


Chart 17. Mean Perimeter Measurements of Board 5 Static Fall and Drag Indentation Tapings

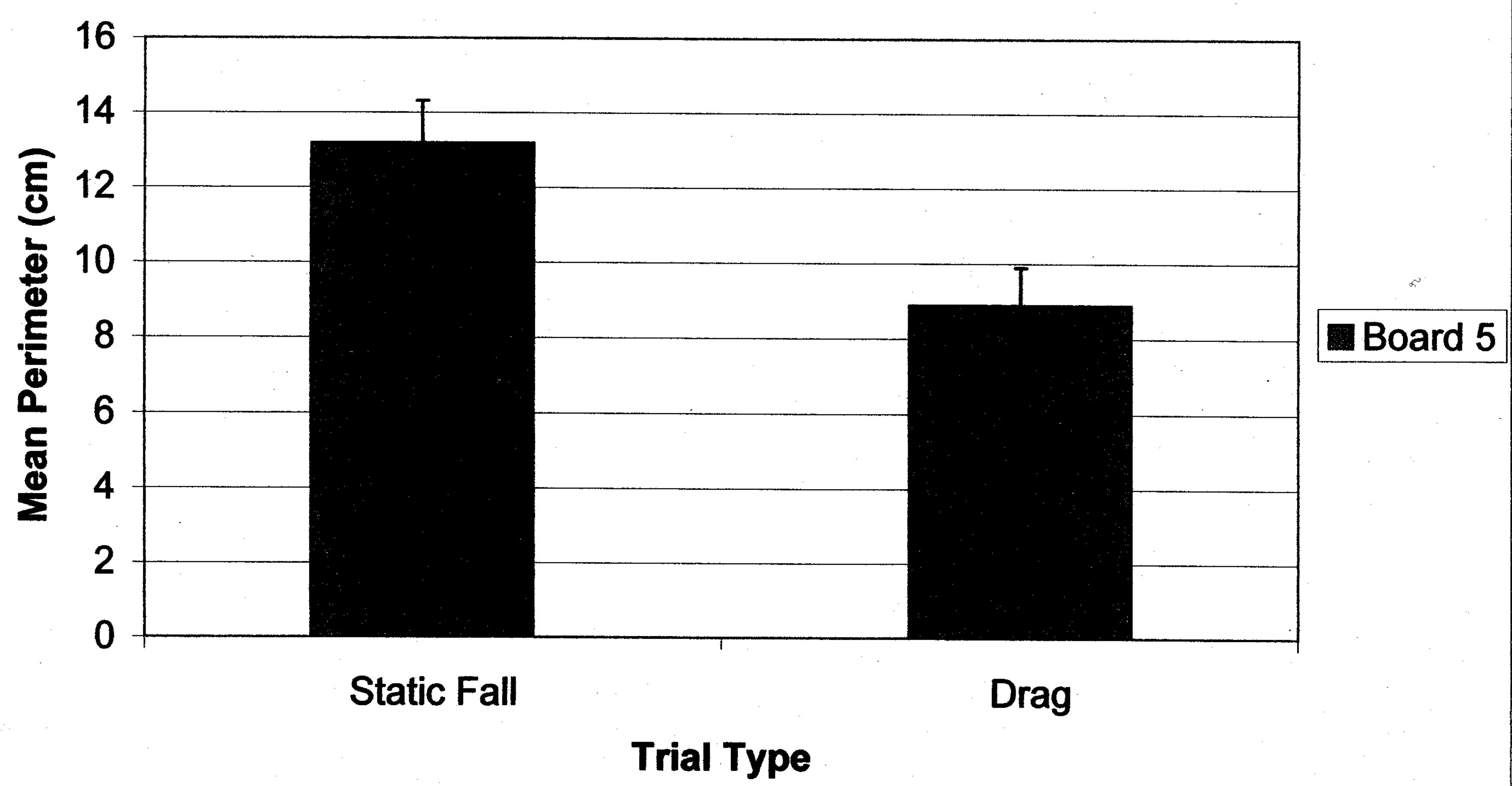


Chart 18. Mean Perimeter Measurements of. Board 6 Static Fall and Drag Indentation Tapings

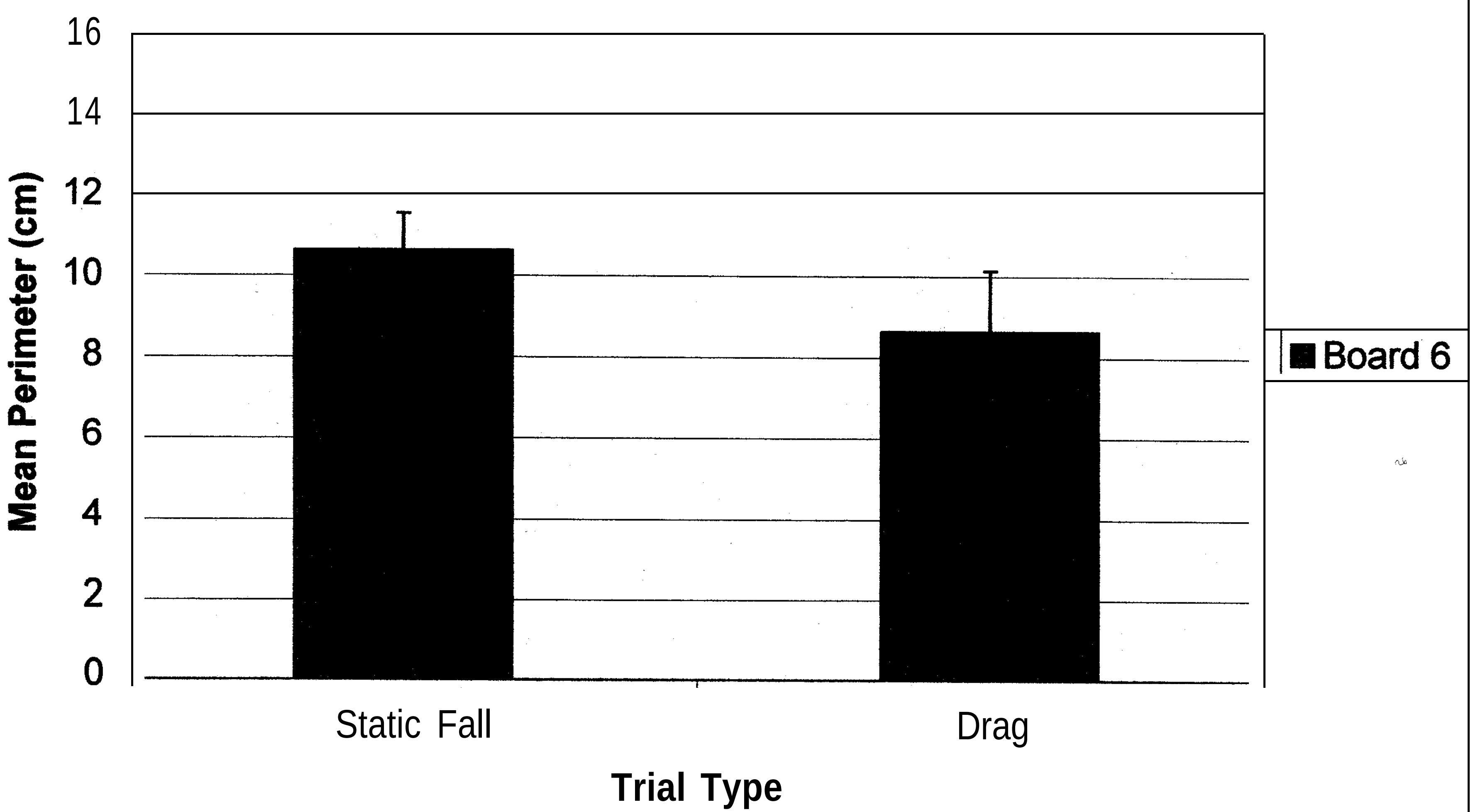


Chart 19. Mean Perimeter Measurements of Board 7 Static Fall and Drag Indentation Tapings

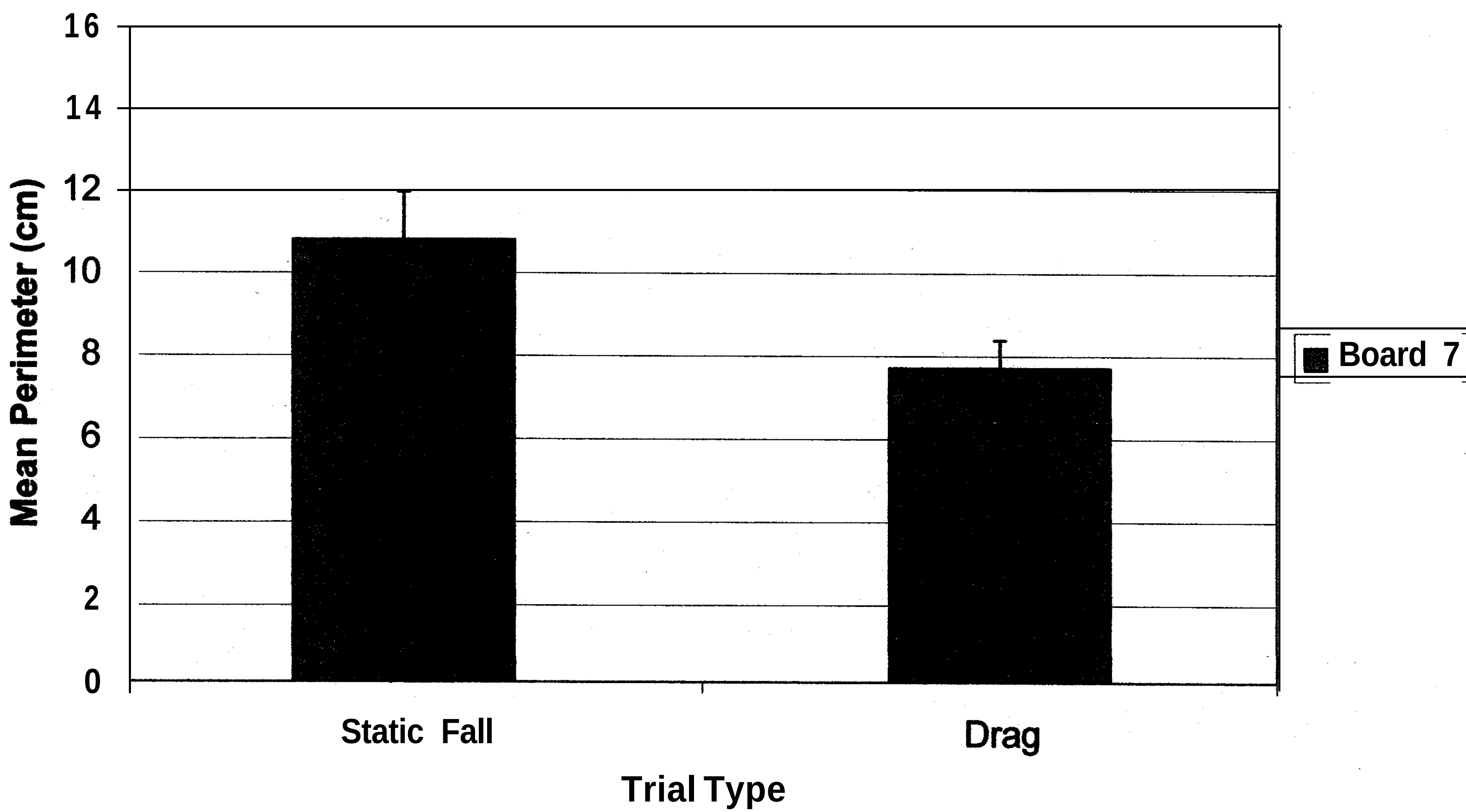


Chart 20. Mean Perimeter Measurements of Board 8 Static Fall and Drag Indentation Tapings

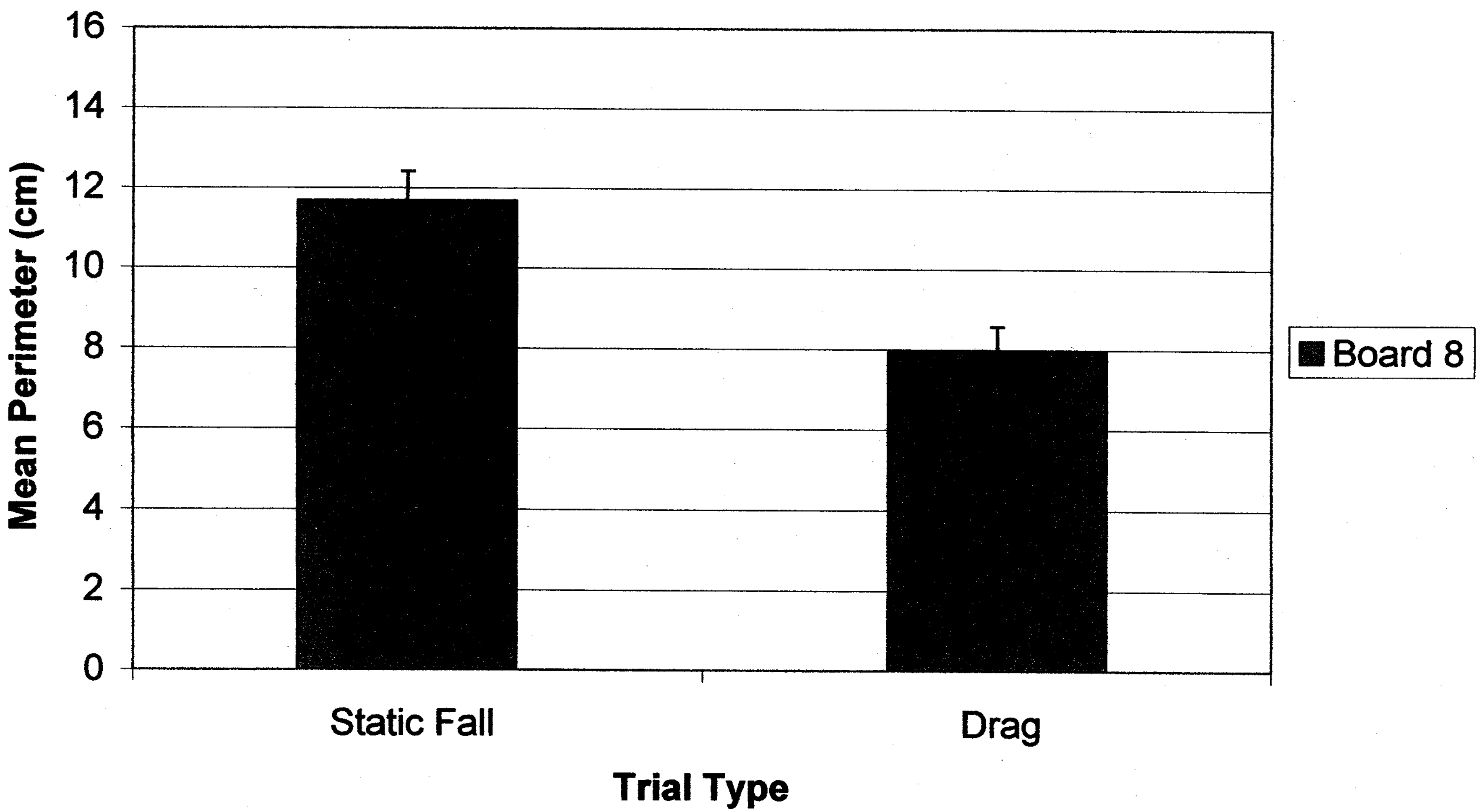


Chart 21. Control Board Measurements for Ligature Side of all Boards.

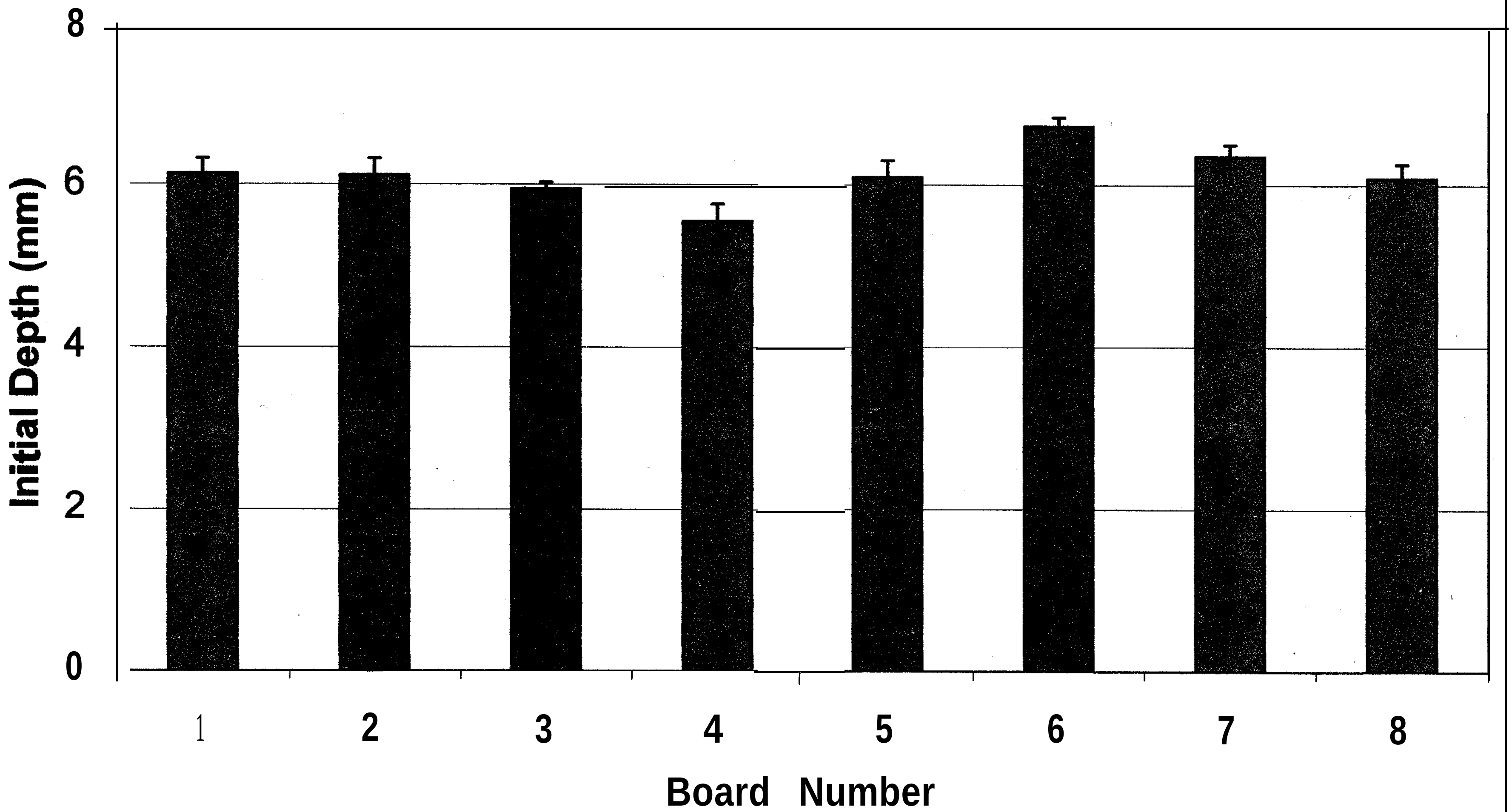


Chart 22. Control Board Measurements of Opposite Side for all Boards.

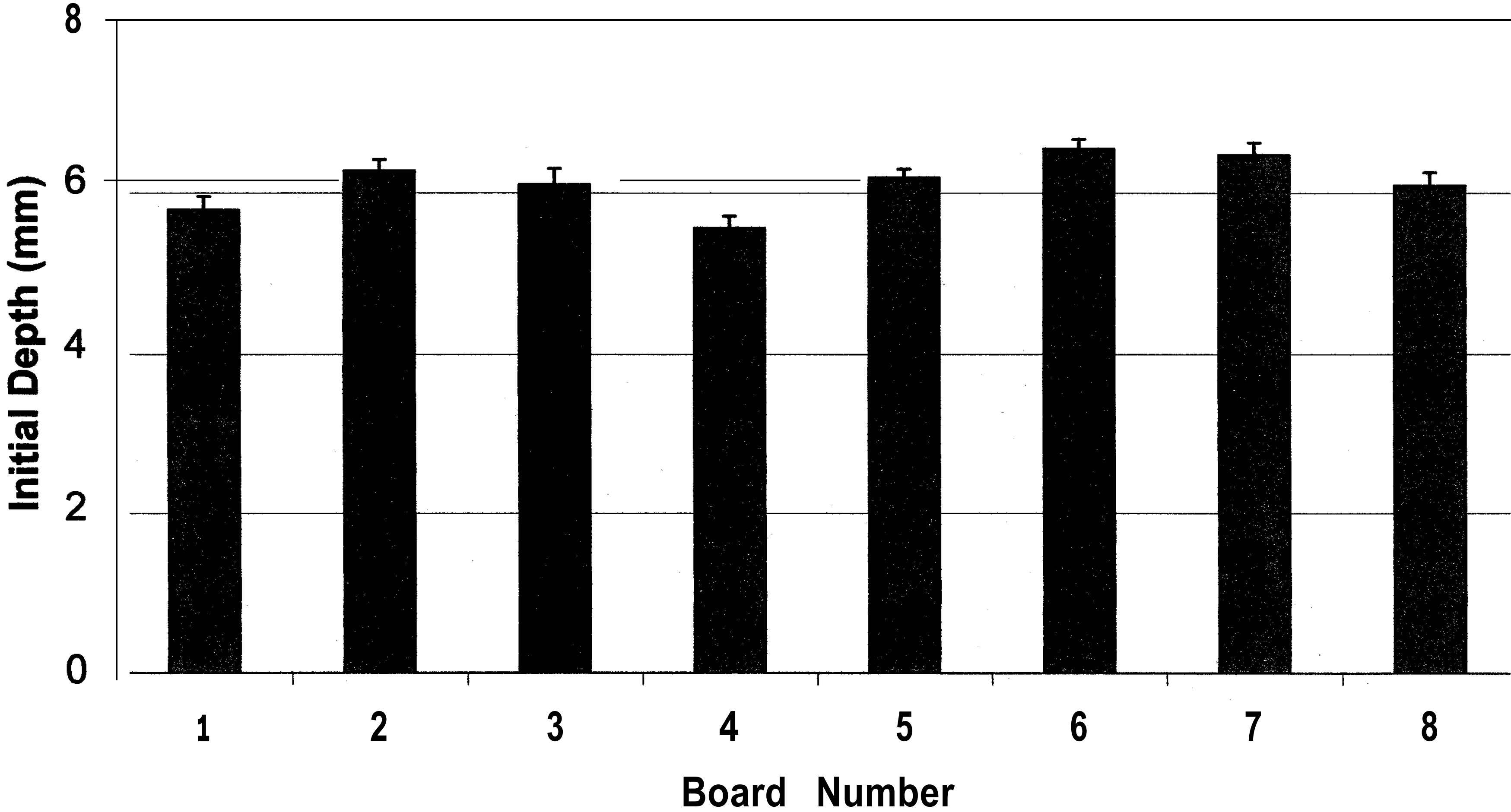


Chart 23. Depth of Indentations for Static Fall Trials comparing Ligature and Opposite Sides for all Boards.

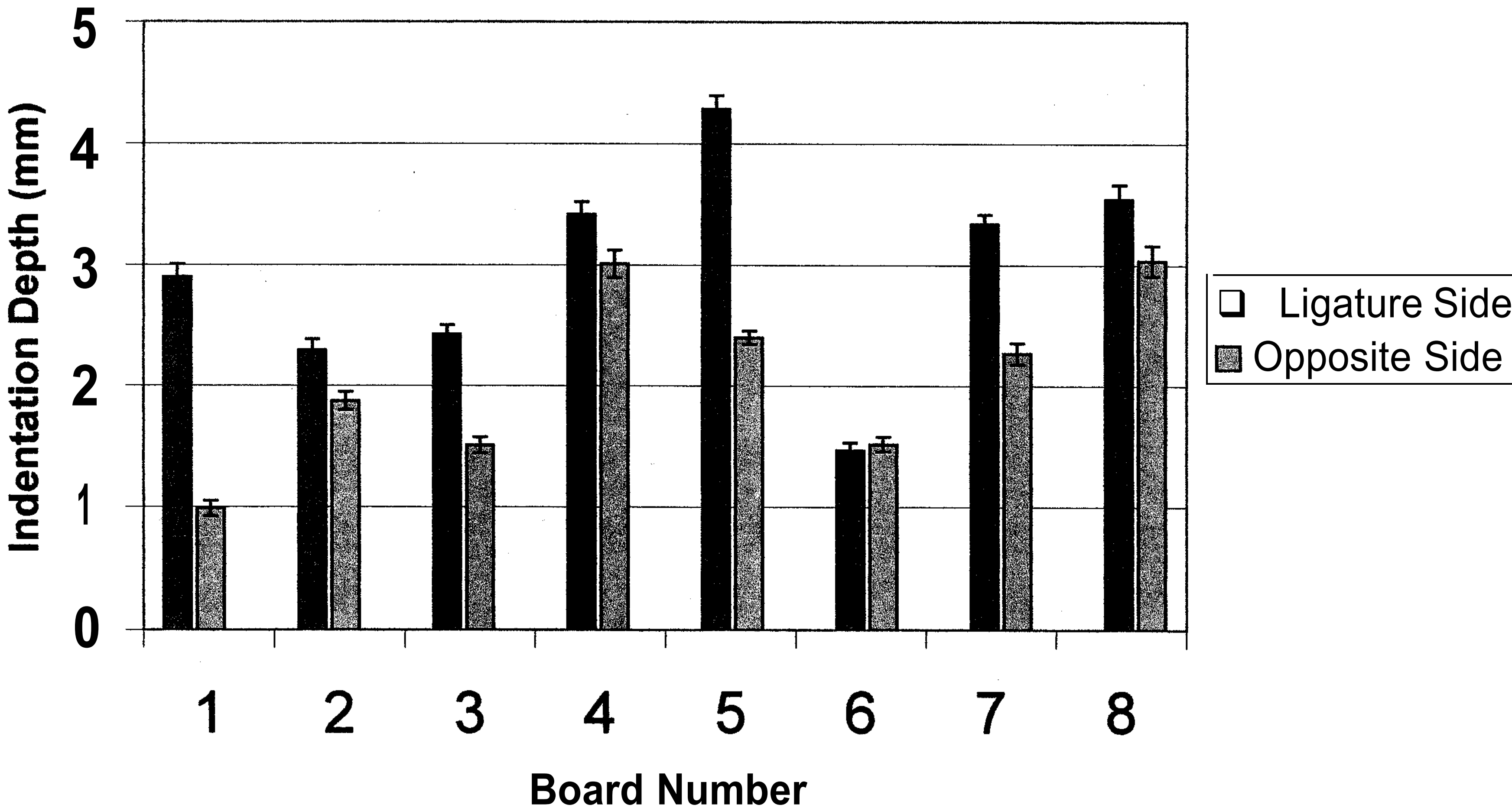


Chart 24. Depth of Indentations for Drag Trials comparing Ligature and Opposite Sides for all Boards.

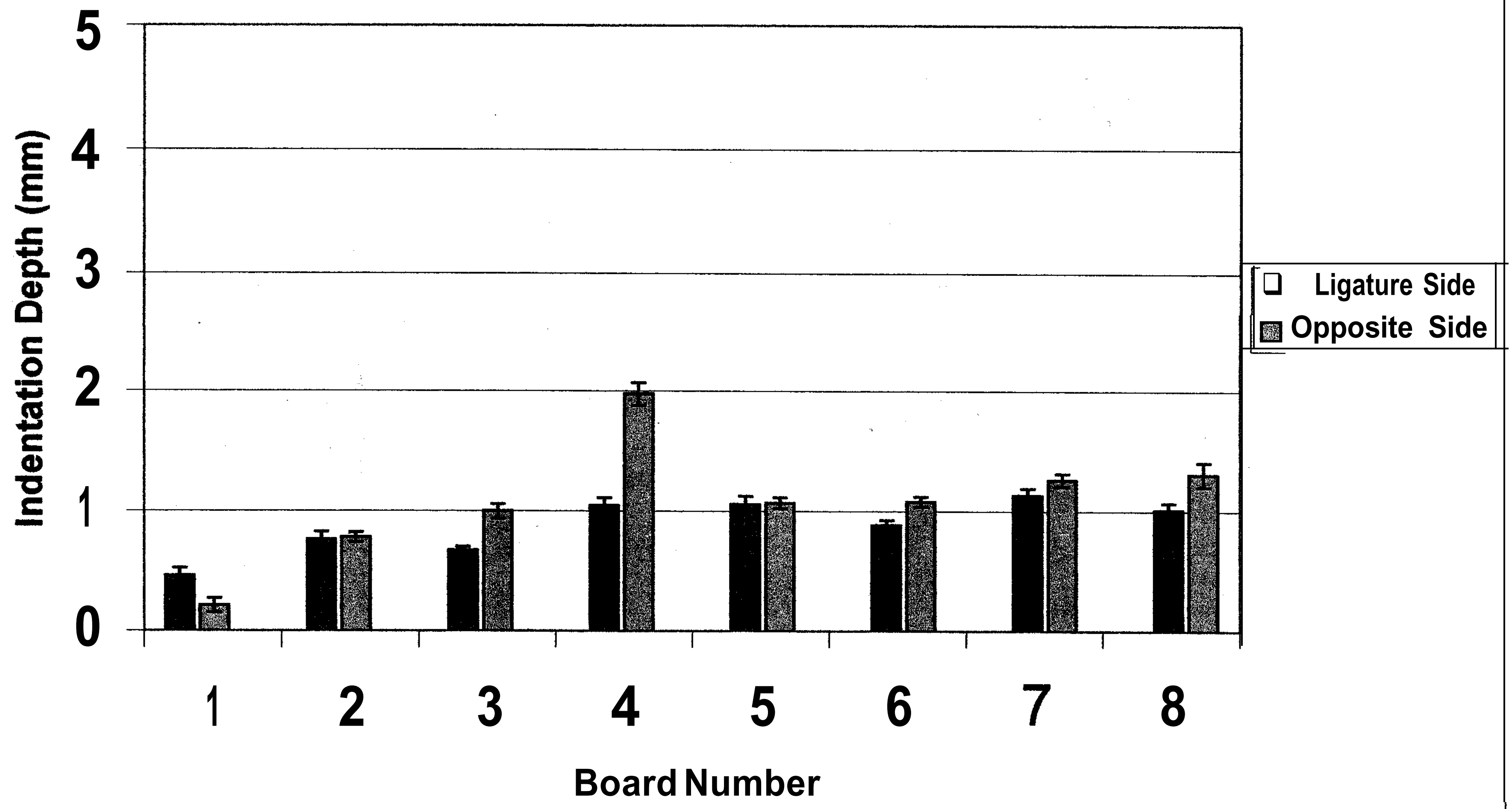


Chart 25. Depth of Indentations for Board 1 Static Fall and Drag Trials - Ligature Side.

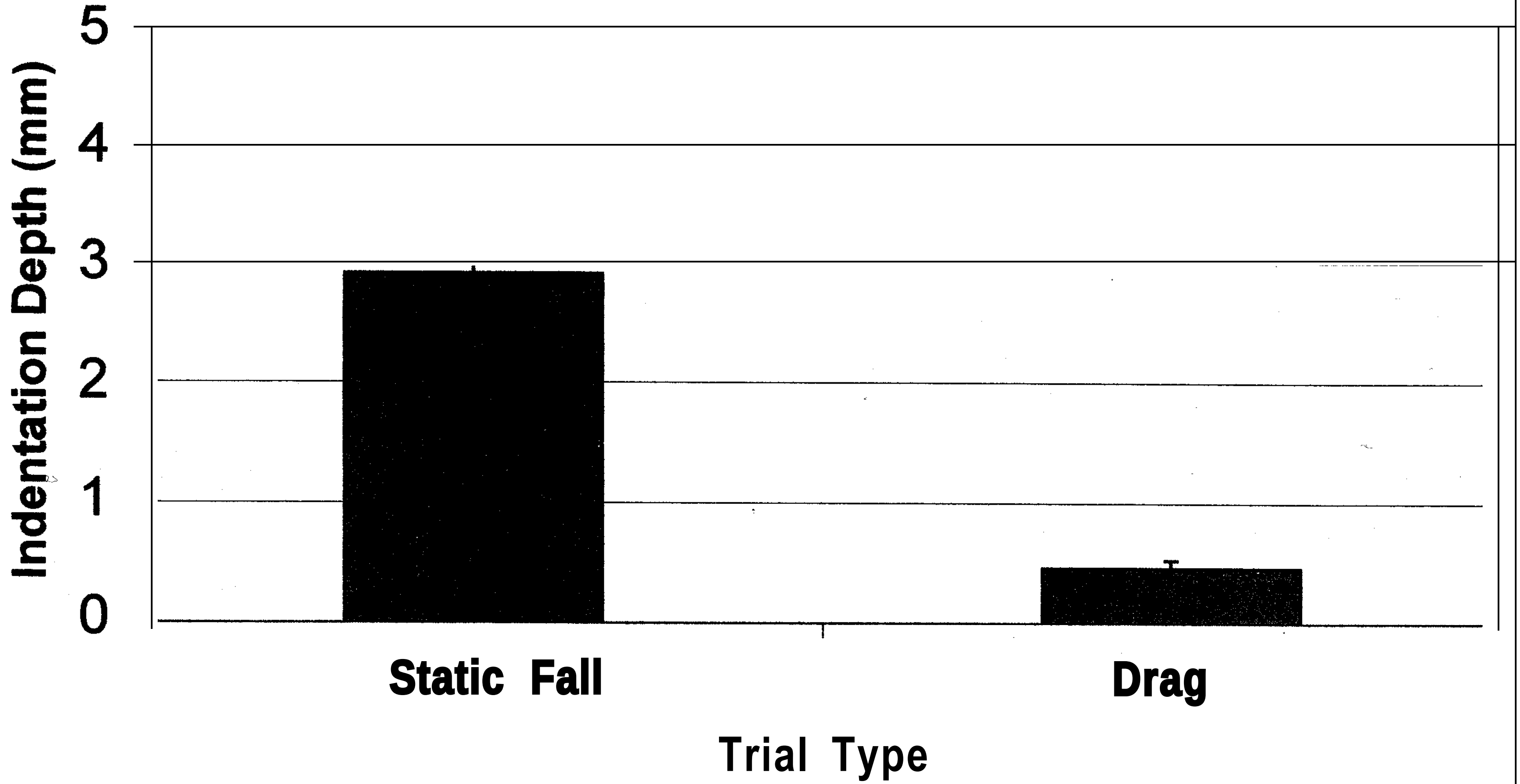


Chart 26. Depth of Indentations for Board 1 Static Fall and Drag Trials - Opposite Side.

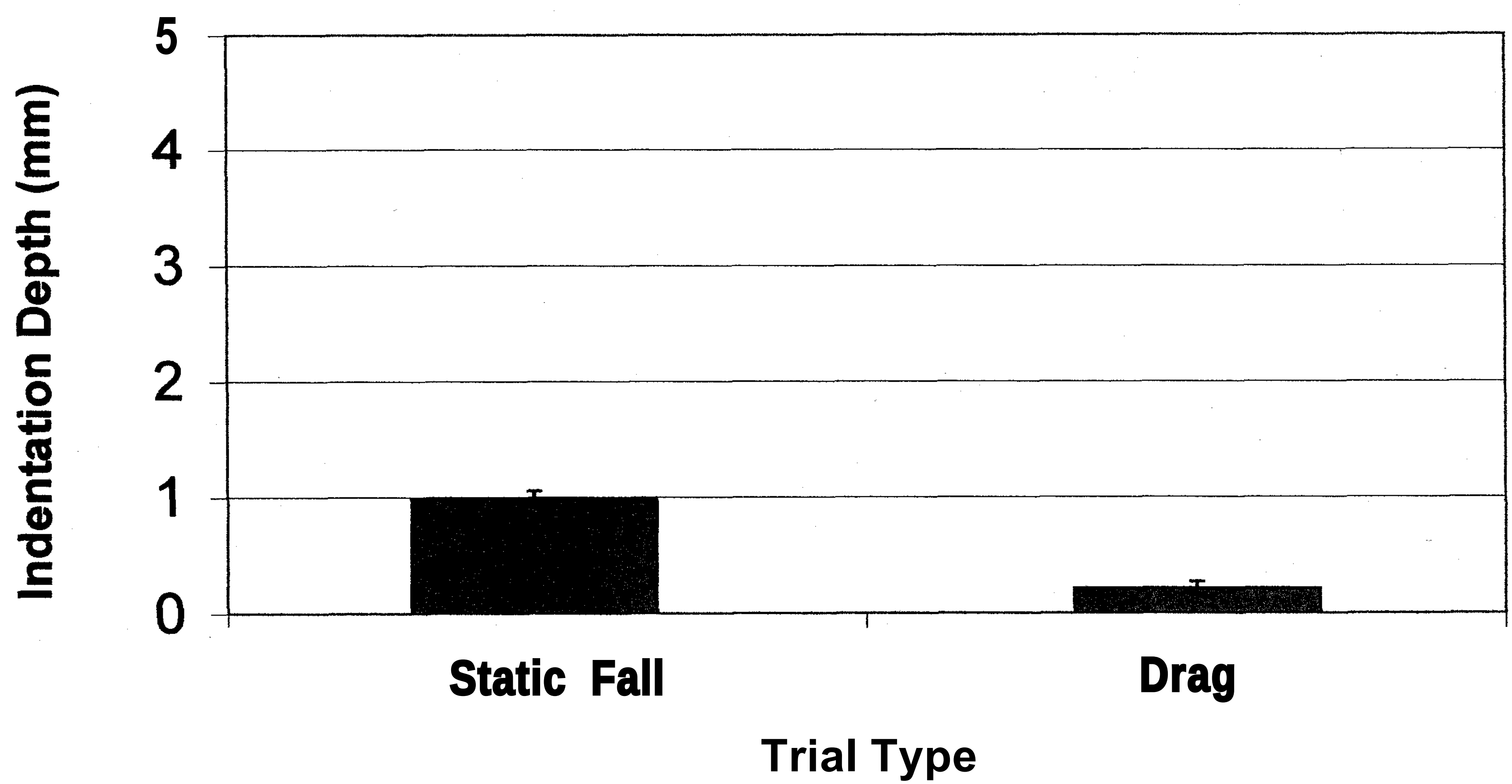


Chart 27. Depth of Indentations for Board 2 Static Fall and Drag Trials - Ligature Side.

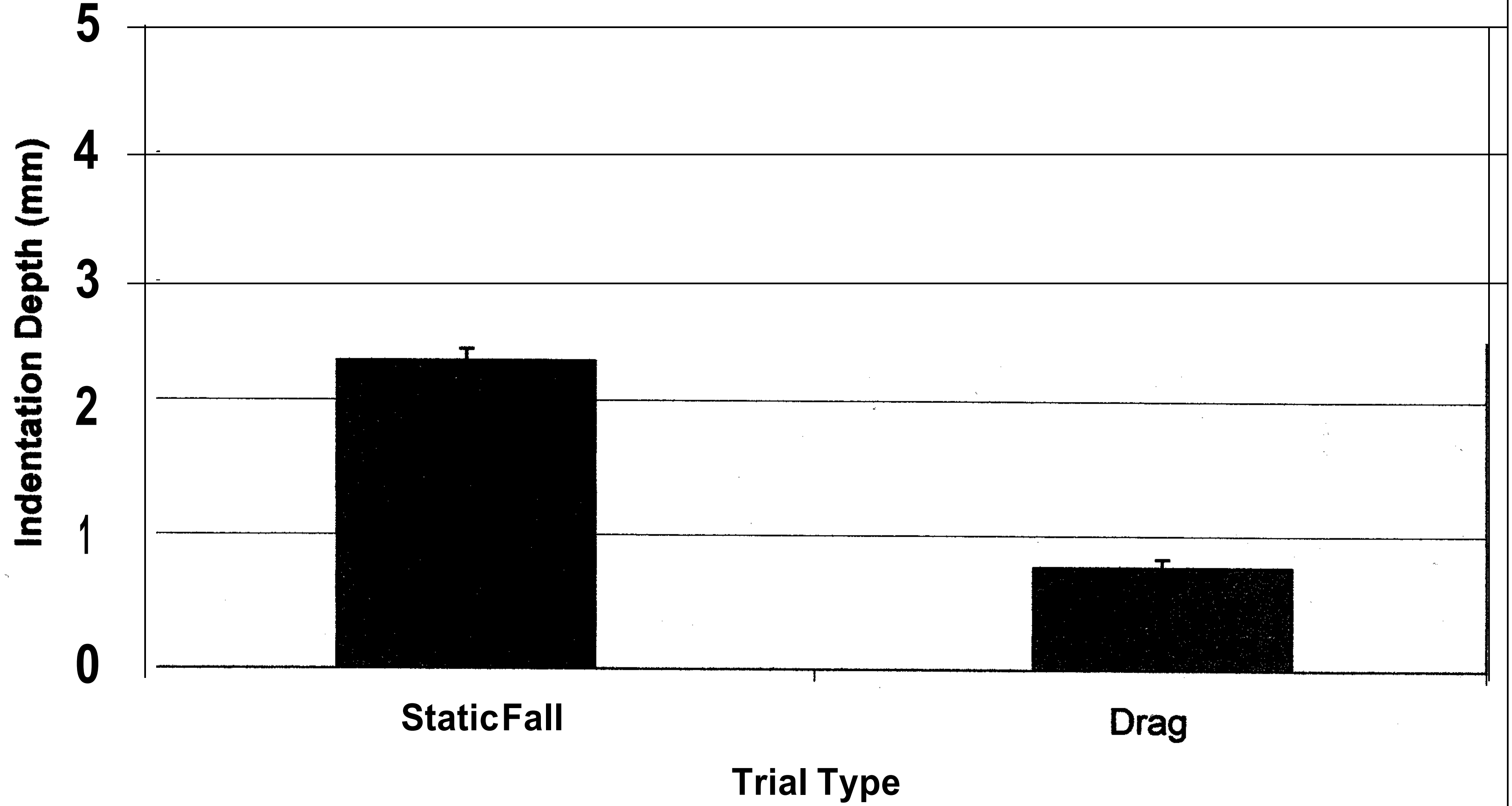


Chart 28. Depth of Indentations for Board 2 Static Fall and Drag Trials - Opposite Side.

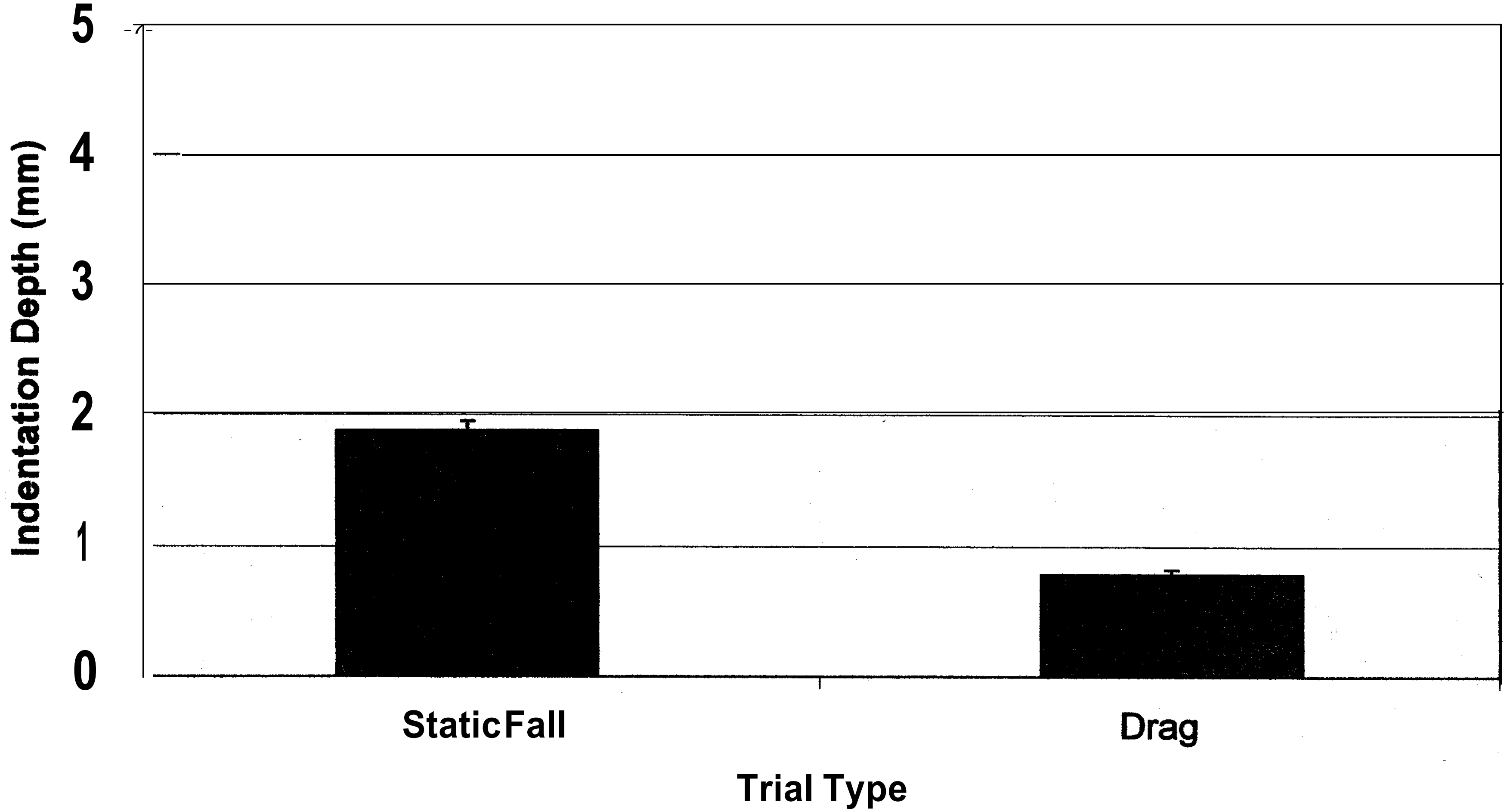


Chart 29. Depth of Indentations for Board 3 Static Fall and Drag Trials - Ligature Side.

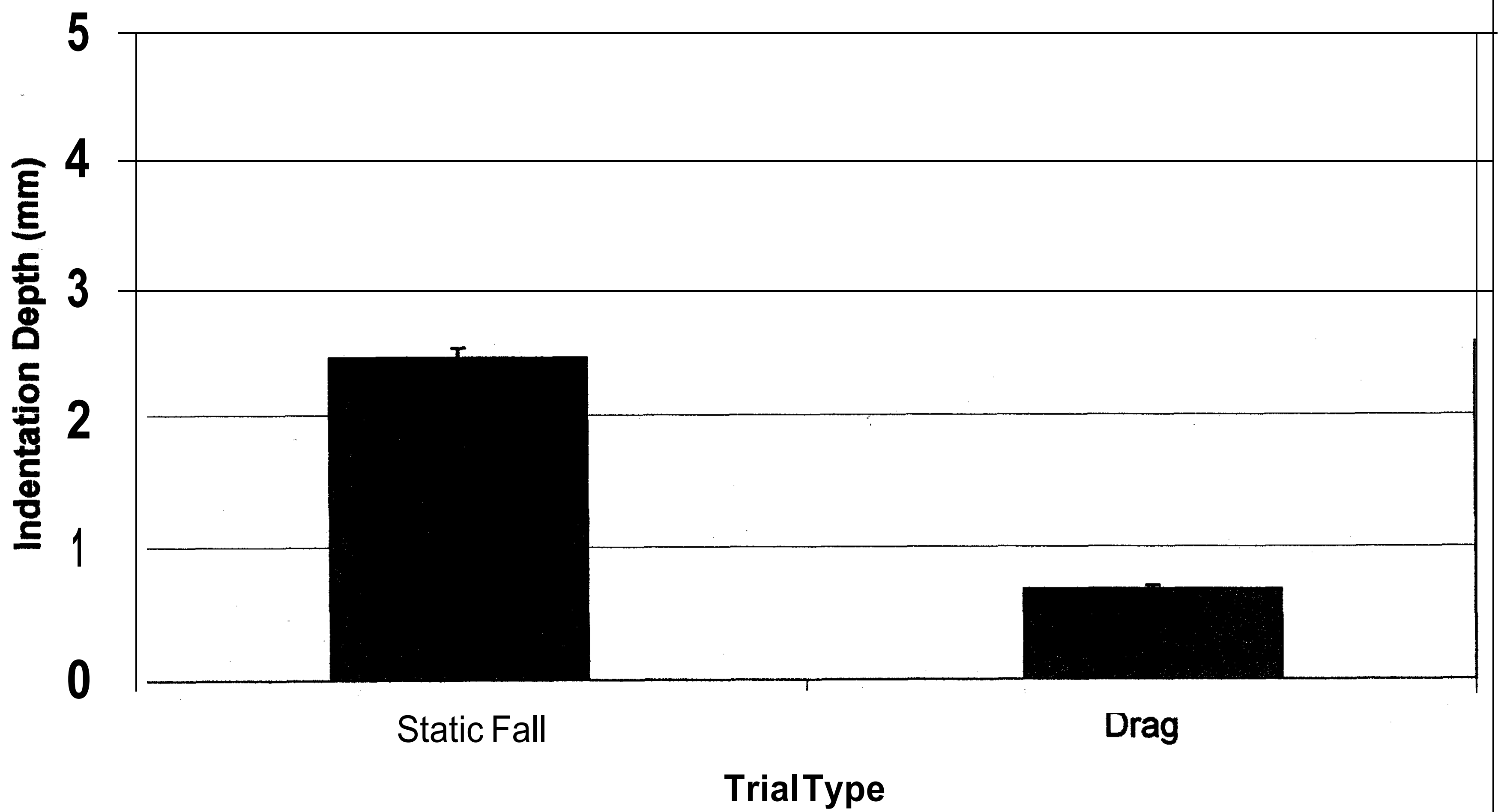


Chart 30. Depth of Indentations for Board 3 Static Fall and Drag Trials - Opposite Side.

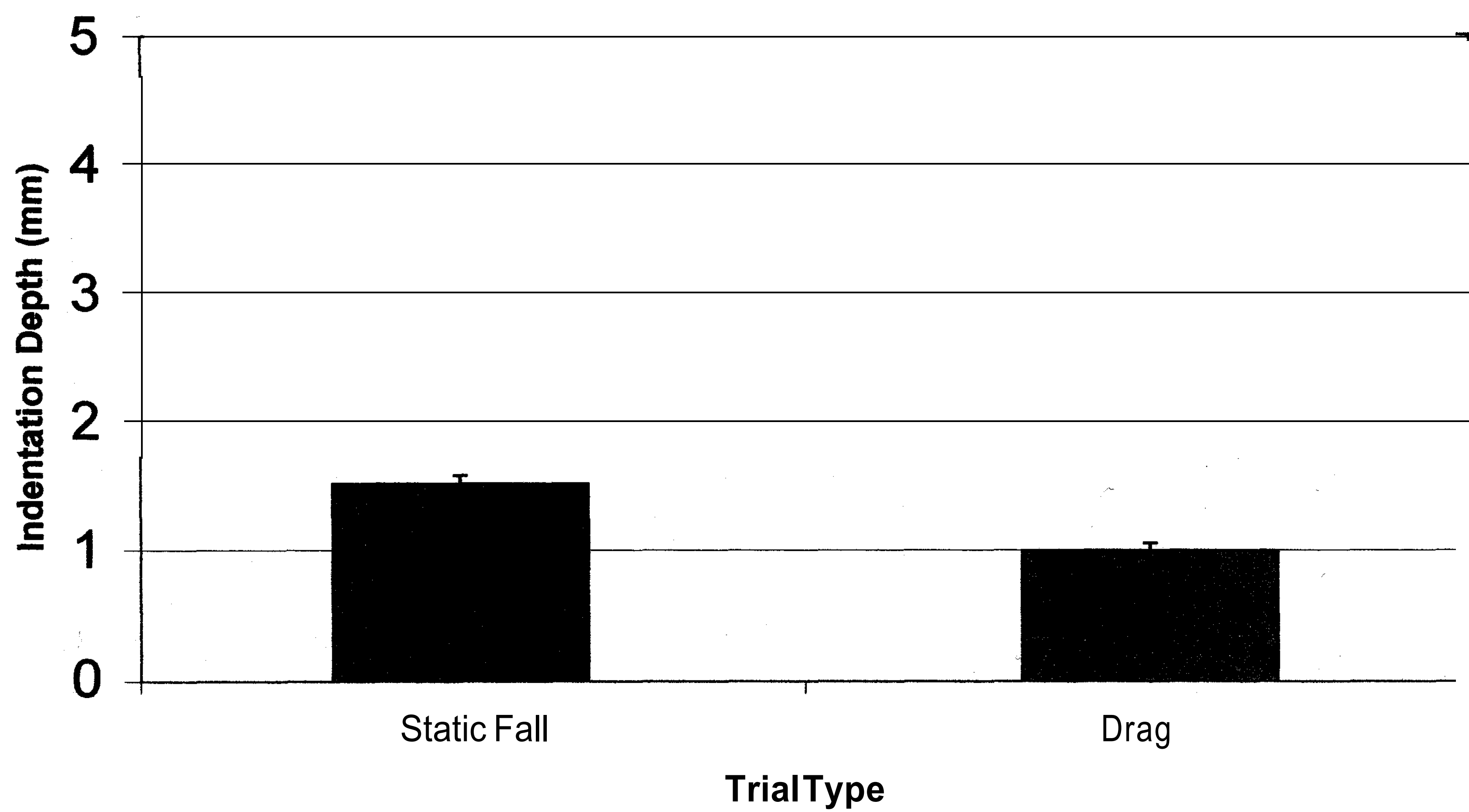


Chart 31. Depth of Indentations for Board 4 Static Fall and Drag Trials - Ligature Side.

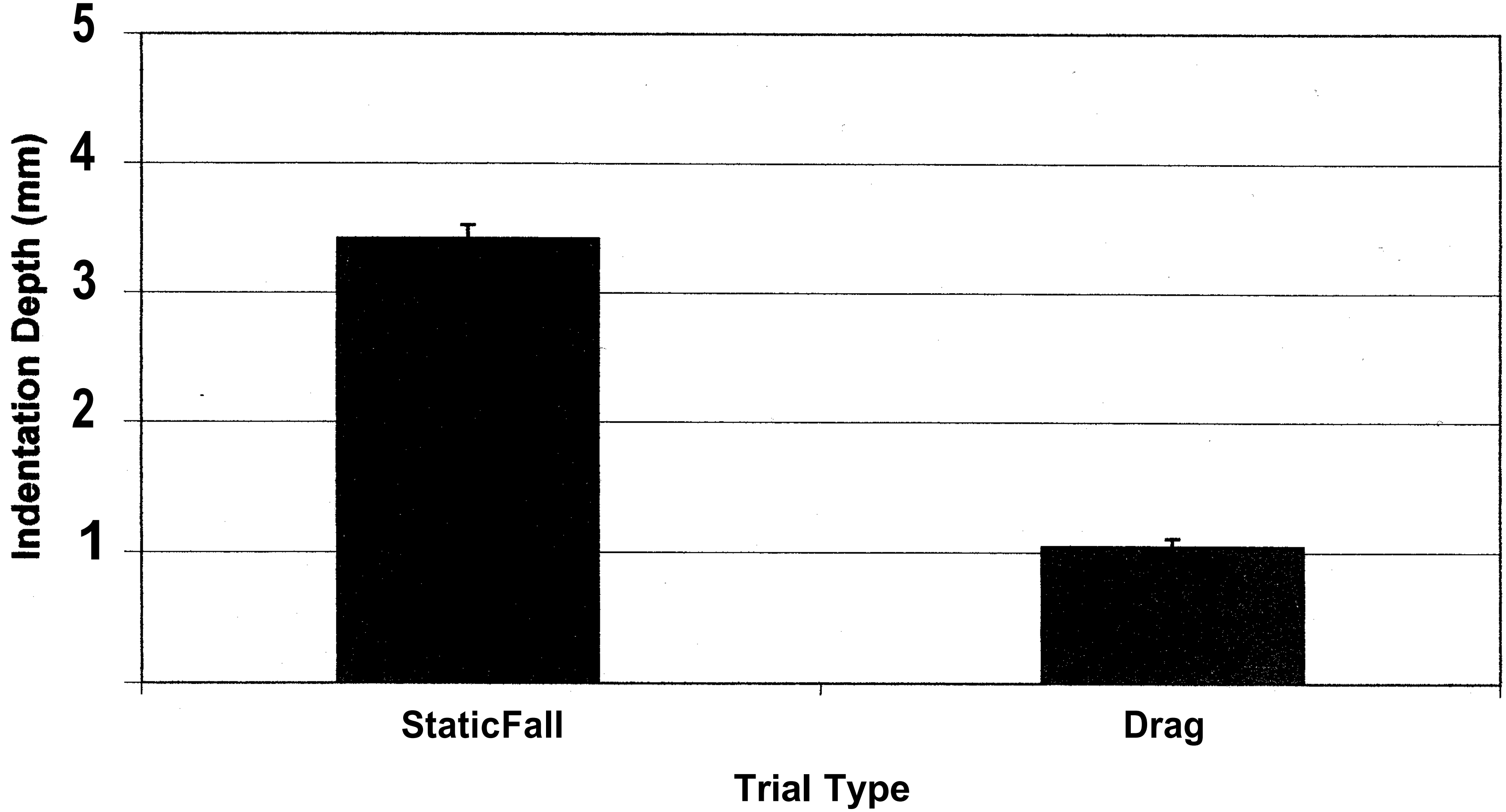


Chart 32. Depth of Indentations for Board 4 Static Fall and Drag Trials - Opposite Side.

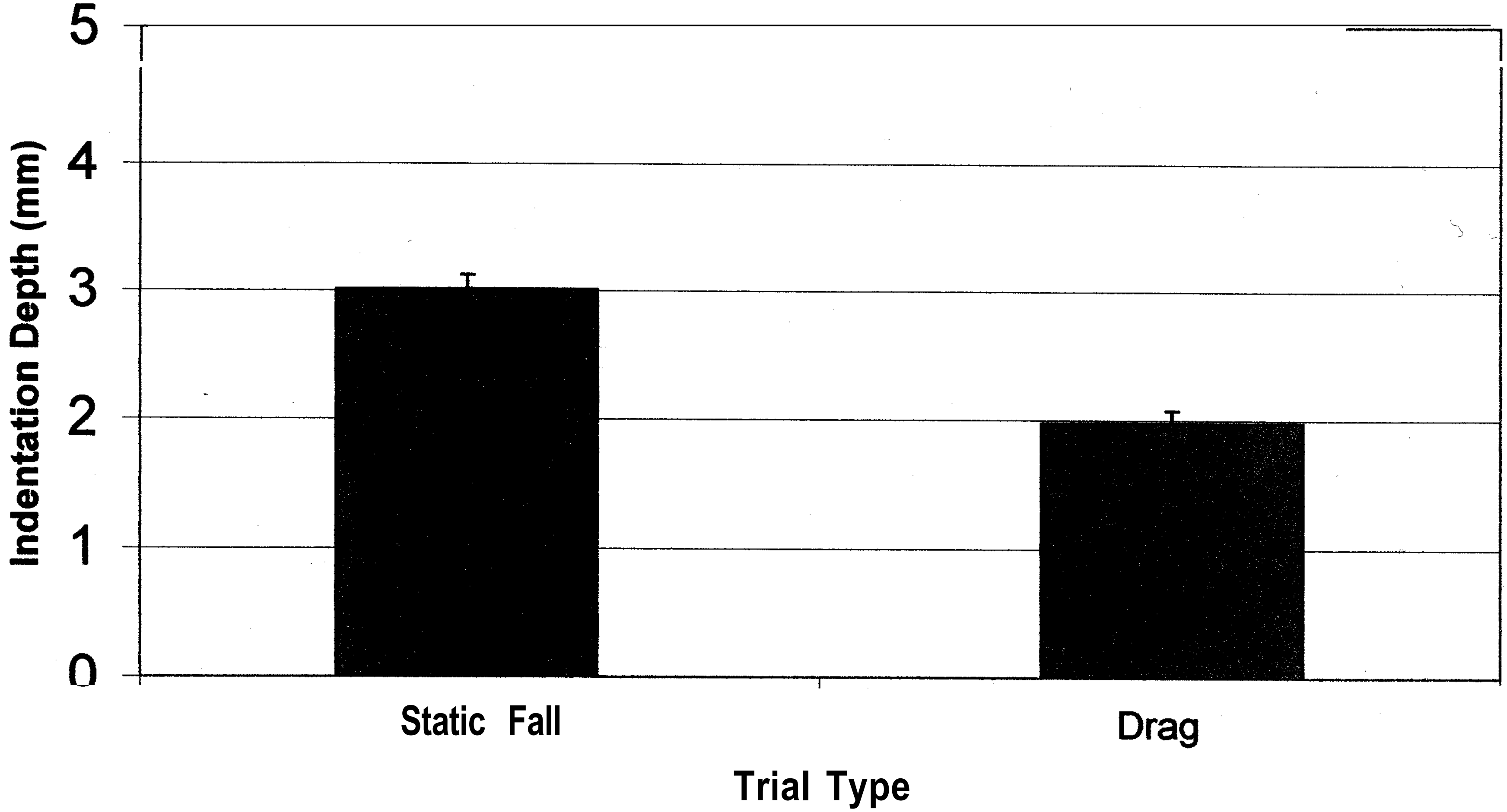


Chart 33. Depth of Indentations for Board 5 Static Fall and Drag Trials - Ligature Side.

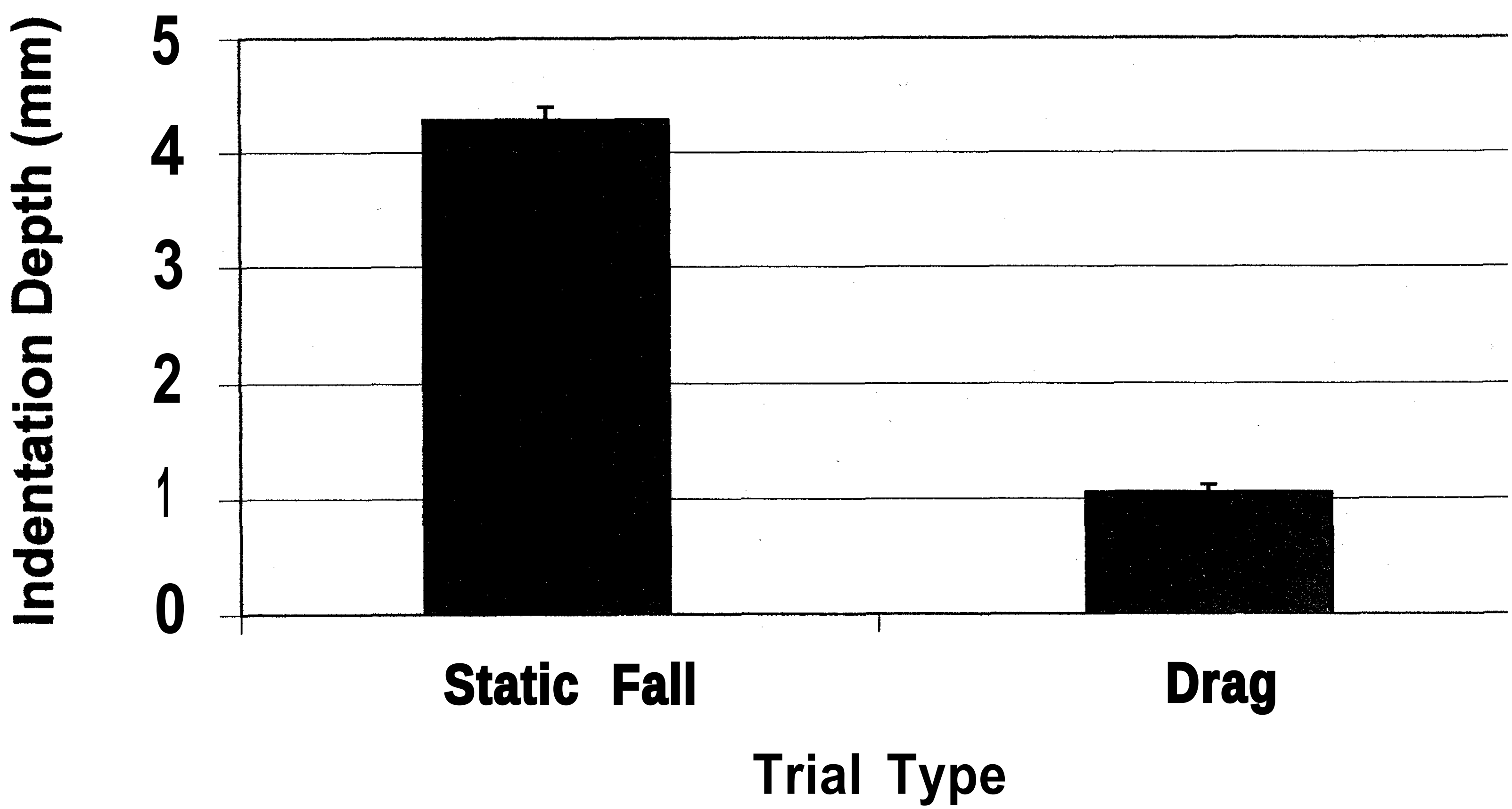


Chart 34. Depth of Indentations for Board 5
Static Fall and Drag Trials - Opposite Side.

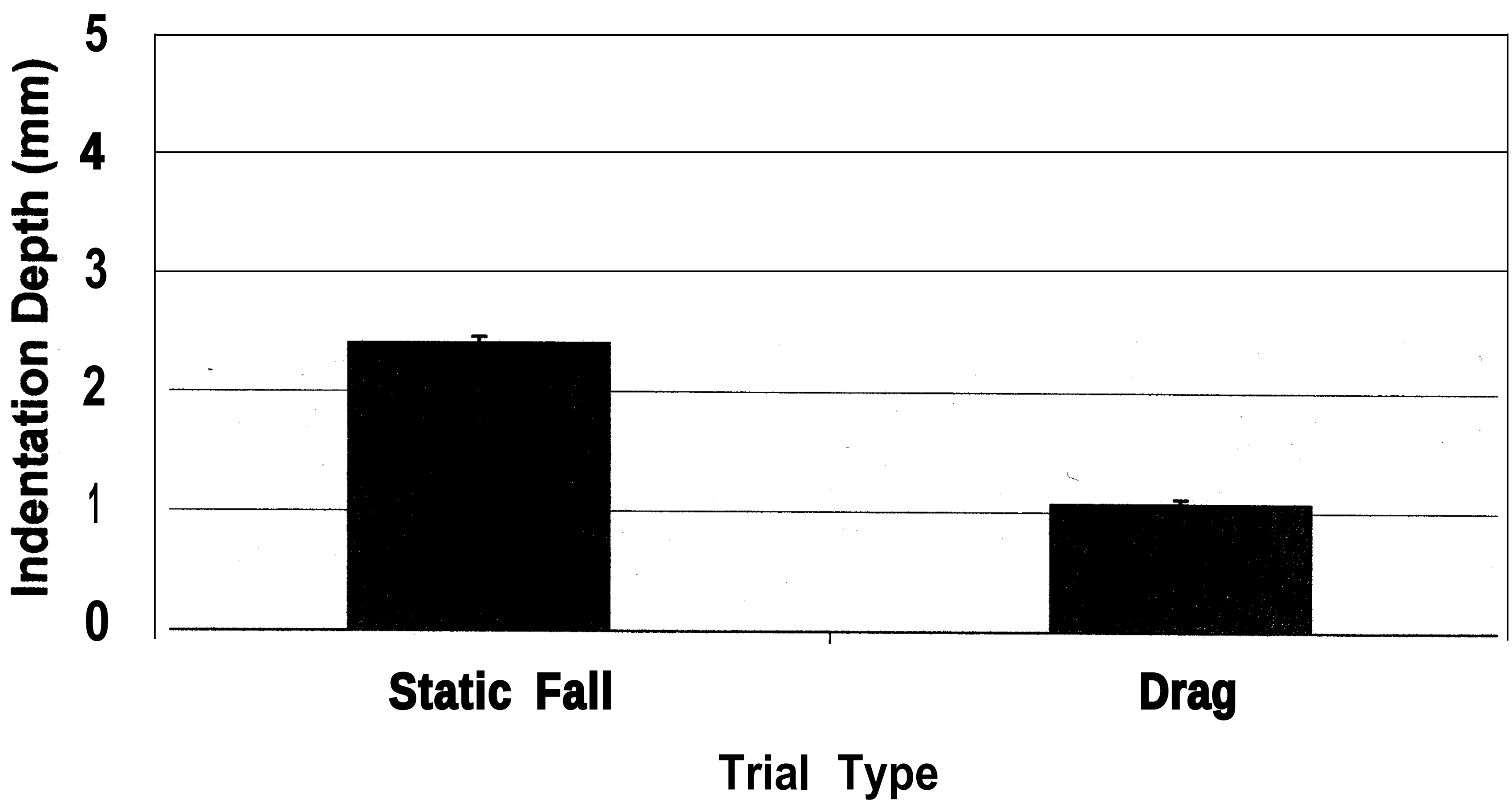


Chart 35. Depth of Indentations for Board 6 Static Fall and Drag Trials - Ligature Side.

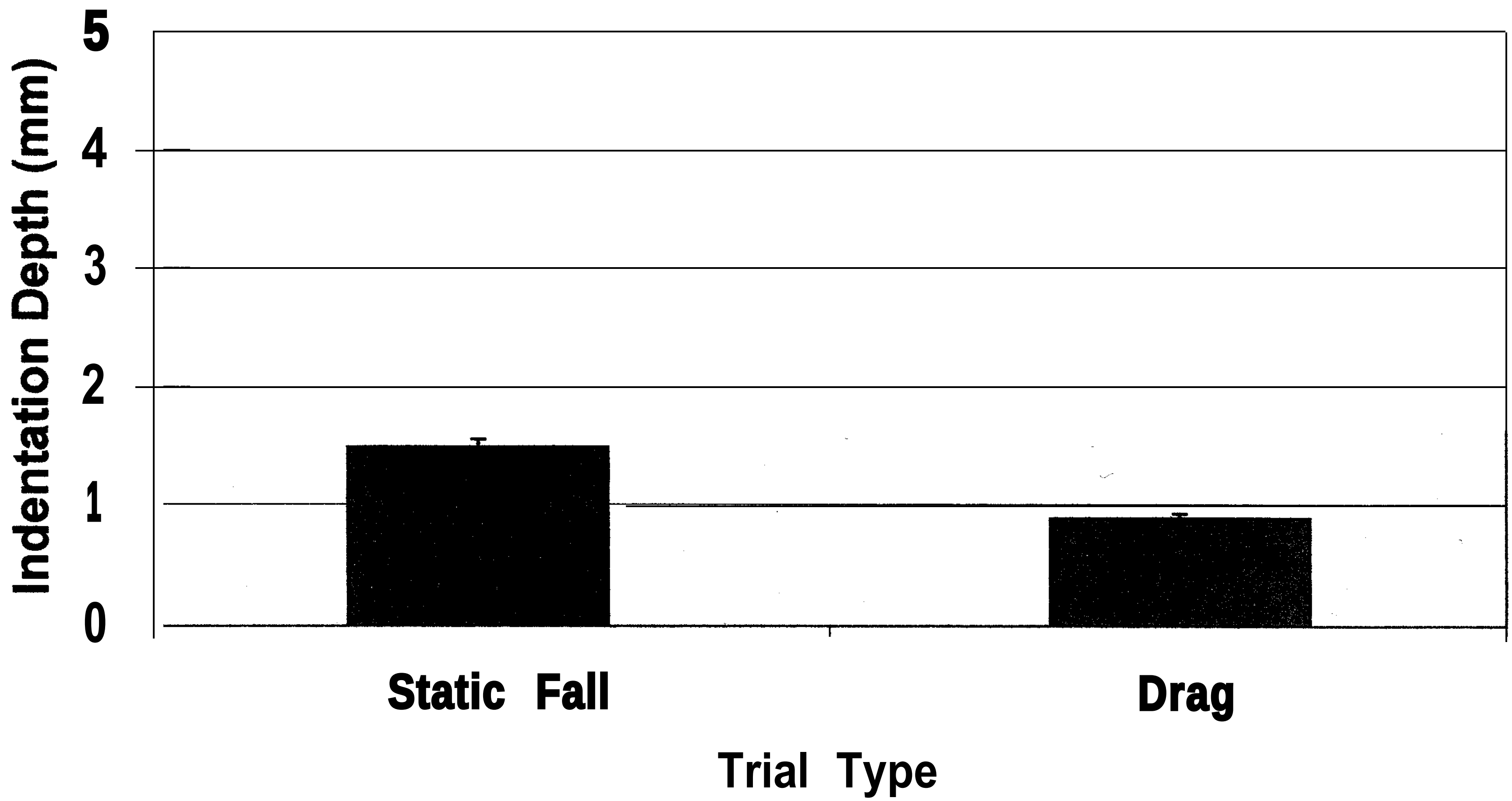


Chart 36. Depth of Indentations for Board 6
Static Fall and Drag Trials - Opposite Side.

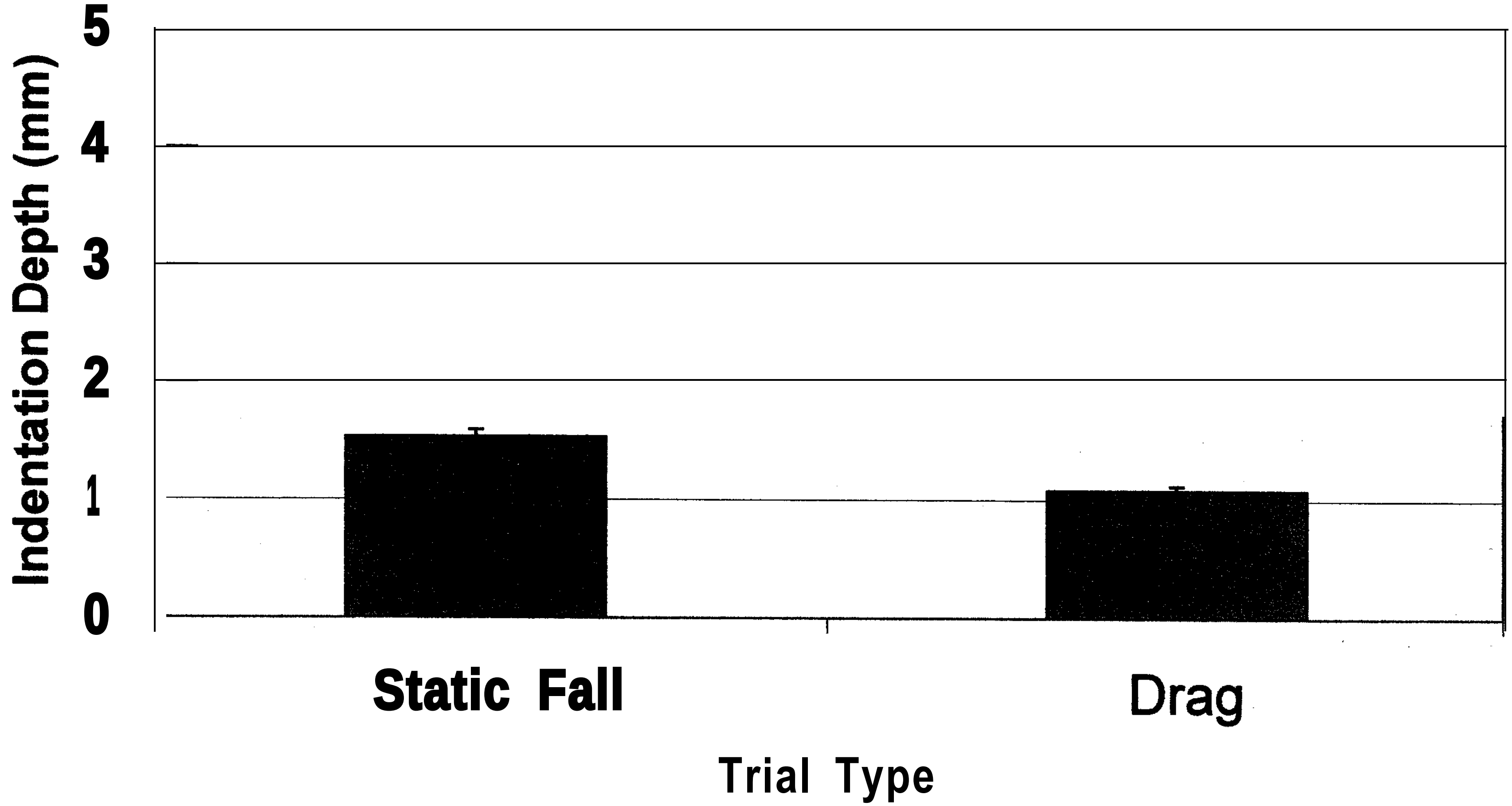


Chart 37. Depth of Indentations for Board 7 Static Fall and Drag Trials - Ligature Side.

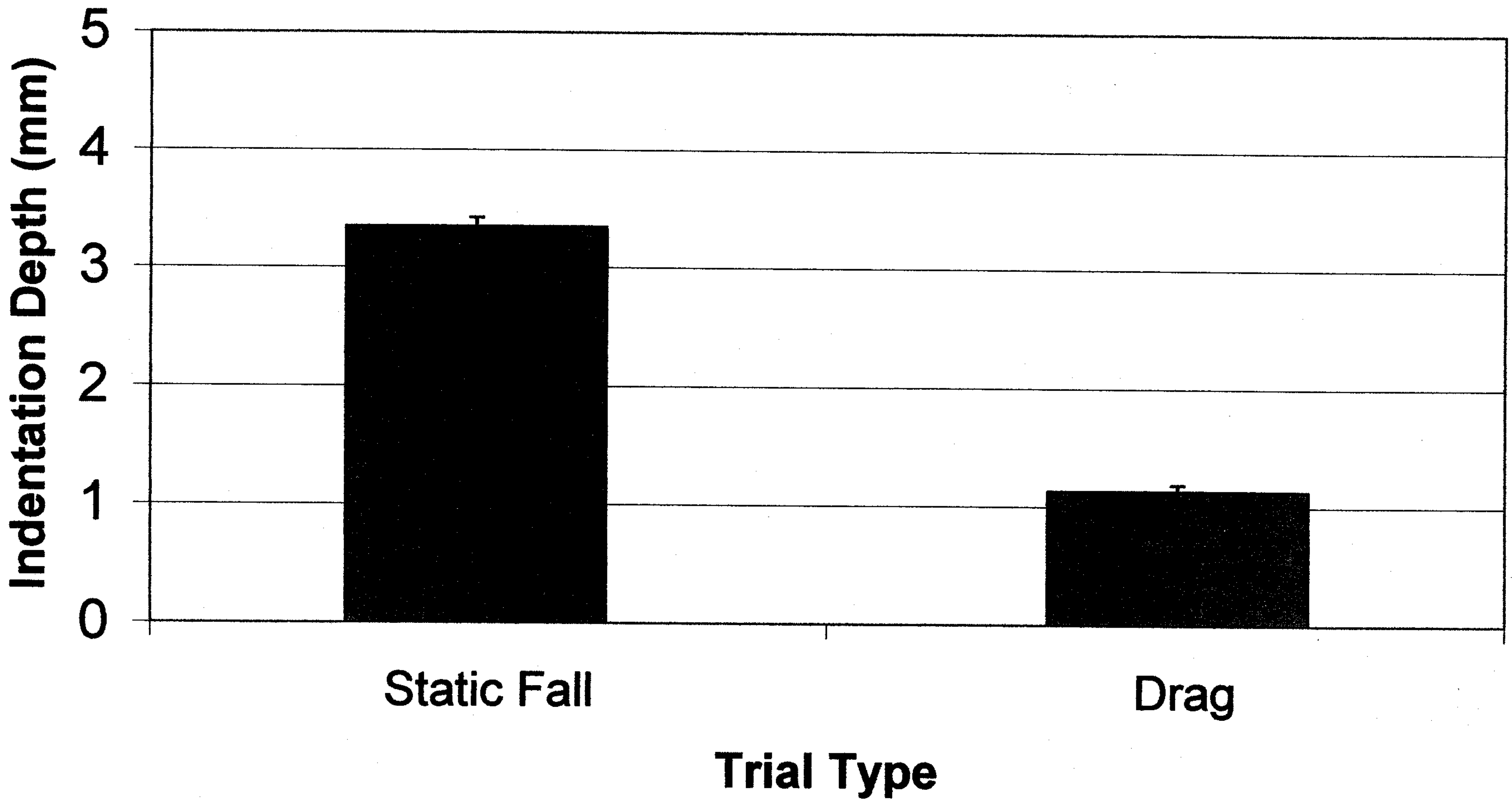


Chart 38. Depth of Indentations for Board 7
Static Fall and Drag Trials - Opposite Side.

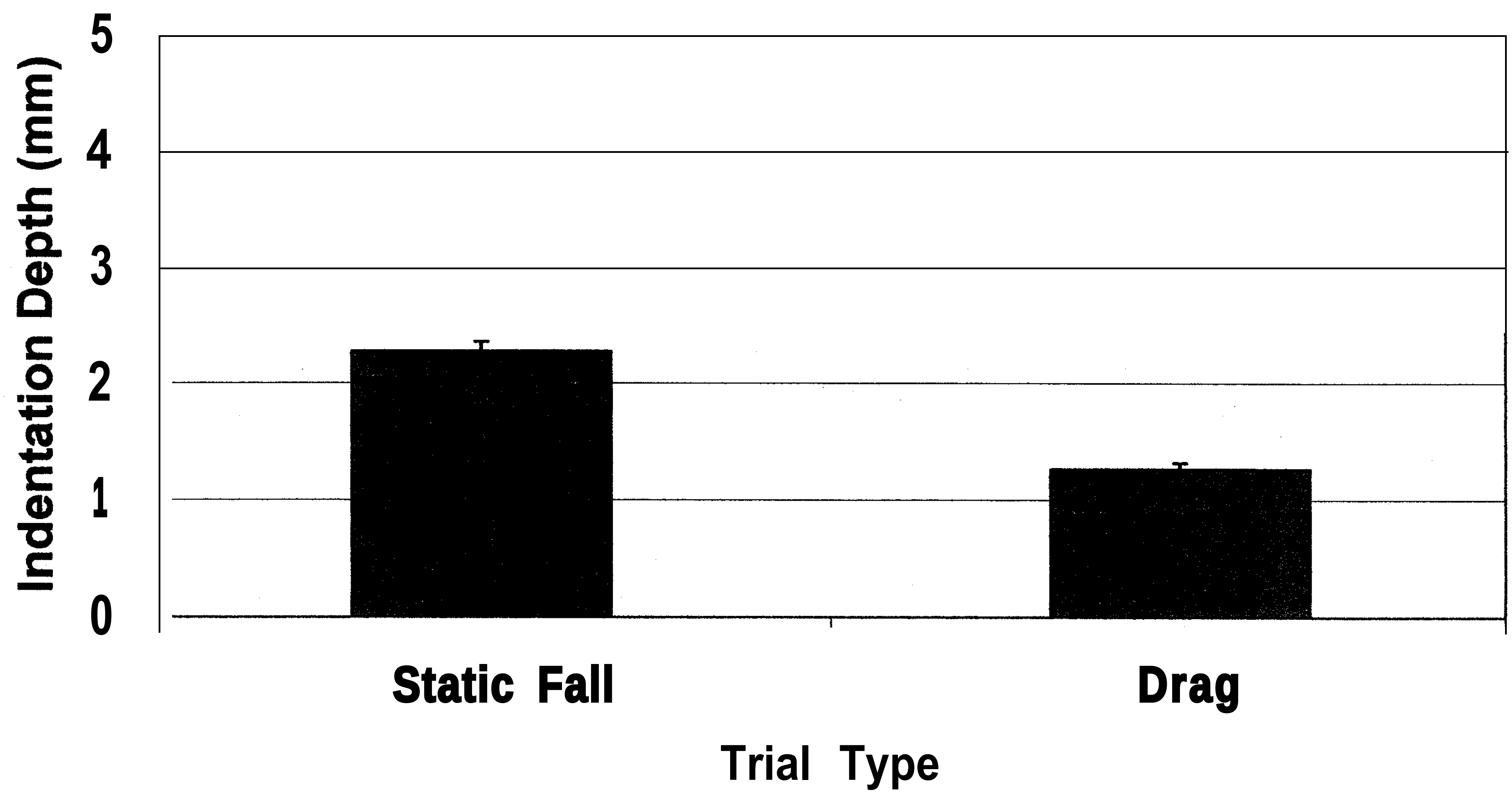


Chart 39. Depth of Indentations for Board 8 Static Fall and Drag Trials - Ligature Side.

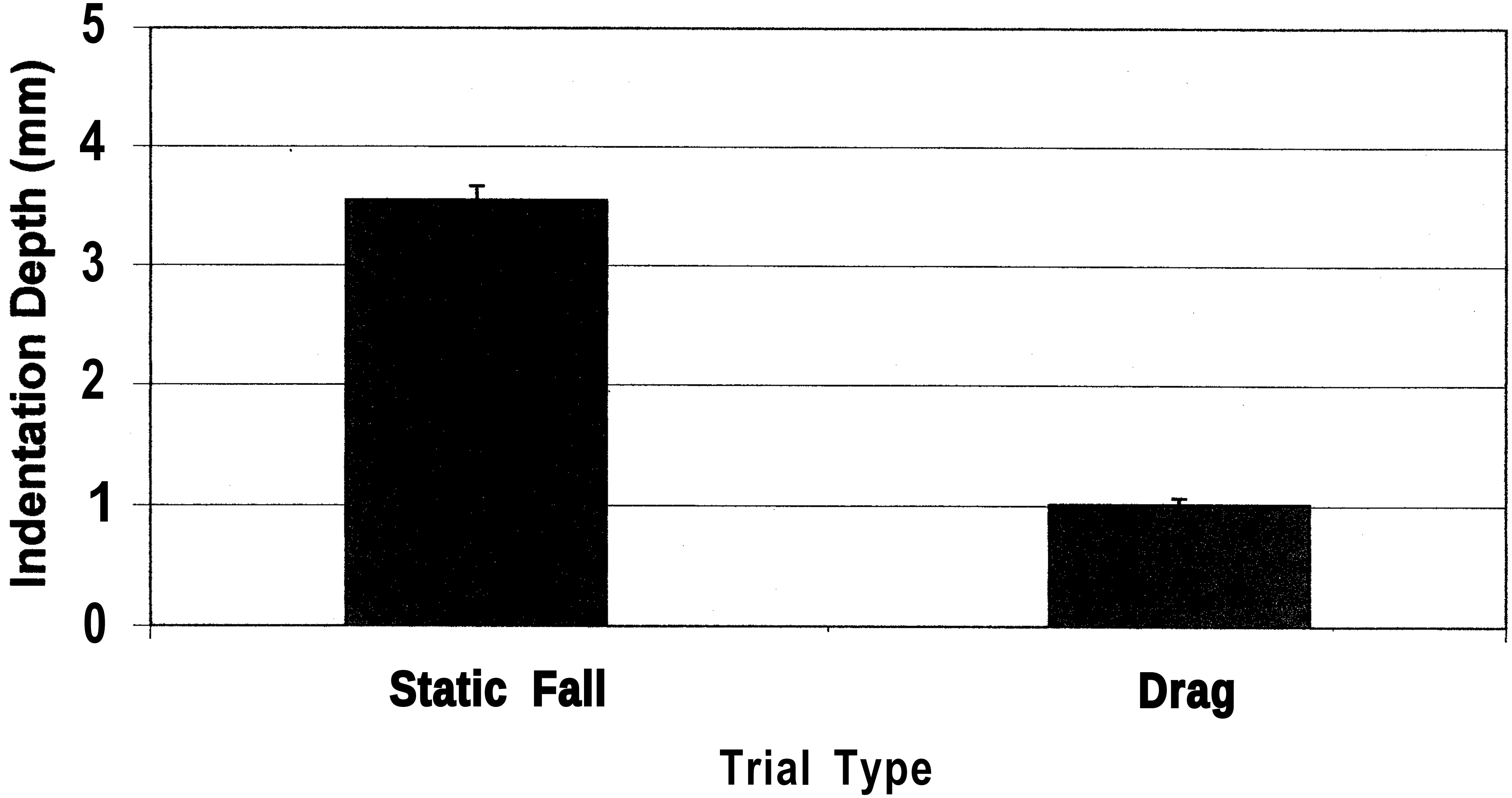
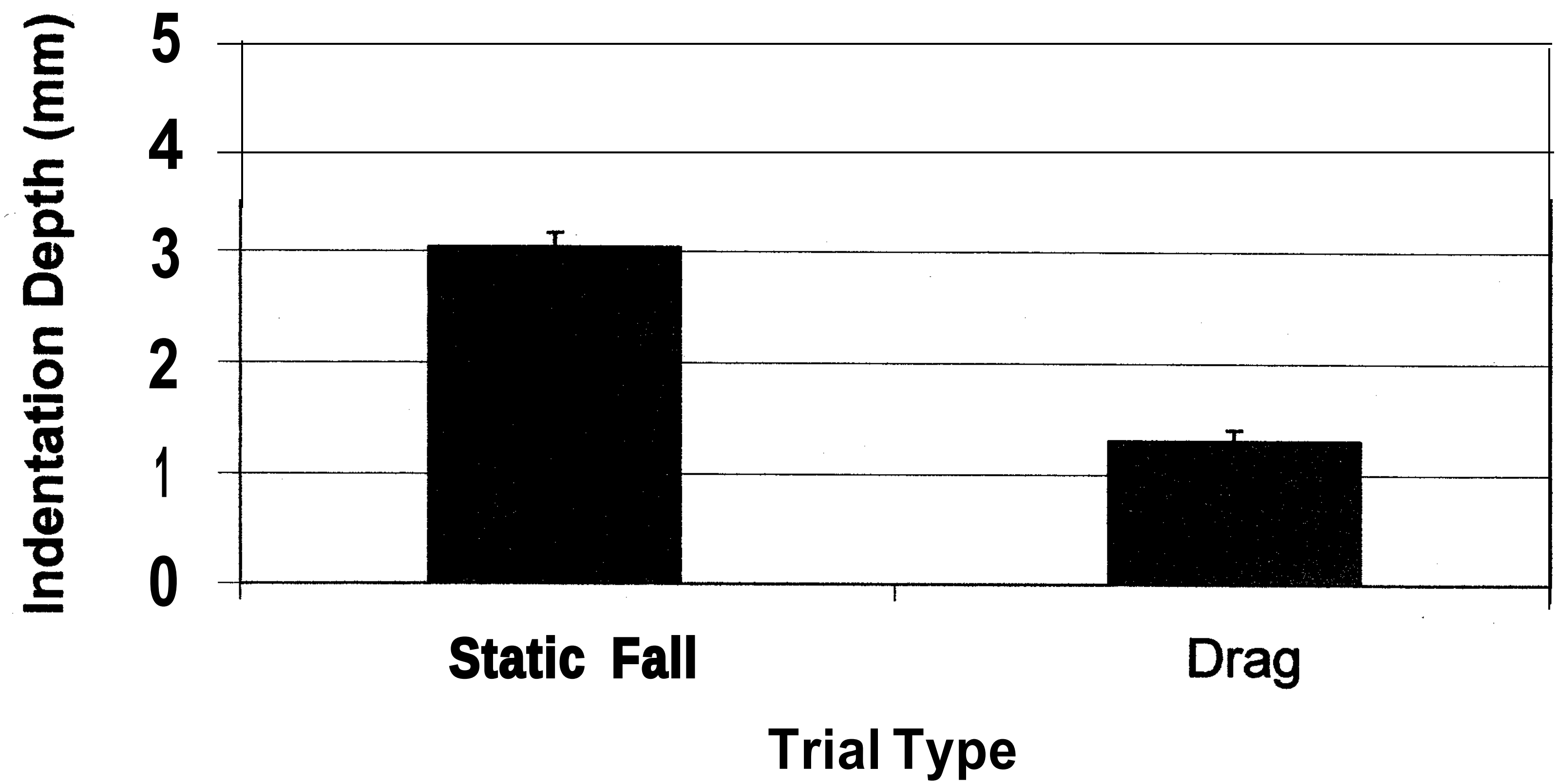


Chart 40. Depth of Indentations for Board 8 Static Fall and Drag Trials - Opposite Side.



APPENDIX E – OMPPAC SURVEY 1998 AND 1999

OMPPAC SURVEY OF 1998 SUDDEN DEATH HANGING CASES - from Central Region Cases at Barrie TISU

	Type of Hanging	Location of Hanging	Stepping Aids	Suspension point type	Ligature Type	Knot type
Case 1	Suicidal	Outside	No	Tree limb	White nylon rope	NR
Case 2	Suicidal	Outside	Possibly metal can?	Tree limb	Yellow polypropylene rope	NR
Case 3	Suicidal	Living room balcony inside	No - jumped from second level	Bannister post	Nylon rope	NR
Case 4	Suicidal	Outside	NR	Tree limb	Dog leash	NR
Case 5	Suicidal	Garage	NR	Rafters	Yellow nylon rope	NR
Case 6	Suicidal	Outside	NR	Tree limb	Leather Belt	N/A
Case 7	Suicidal	Inside trailer	NR	Ceiling Joist	Black extension cord	NR
Case 8	Suicidal	Garage	Kitchen chair?	Beam	Yellow rope	NR
Case 9	Suicidal	Outside	Grocery cart	Tree limb	White rope	NR

	Knot location	Hair/clothing caught in ligature	Complete or incomplete suspension	Suicide Note	Dirt/dust	Indentations
Case 1	NR	NR	Complete - 3' 4" off ground	Yes	Bark on pants	NR
Case 2	NR	Left glove caught	Complete - 1 1/2" off ground	No	Bark on pants	NR
Case 3	Right of neck to back	NR	NR	No	NR	NR
Case 4	NR	NR	Complete - 20' off ground	Yes	NR	NR
Case 5	NR	NR	NR	Yes	NR	NR
Case 6	NR	NR	NR	Yes	NR	NR
Case 7	NR	NR	NR	Yes	NR	NR
Case 8	NR	NR	NR	Yes	NR	NR
Case 9	NR	NR	NR	NR	NR	NR

	Fibres	Drag marks	Signs of struggle	Measurements taken	Photographs	Main Evidence
Case 1	NR	NR	NR	Yes	Yes	Rope, note pad
Case 2	NR	NR	No	Yes	Yes	Rope w metal loop
Case 3	NR	NR	No	Yes	Yes	Rope, bio samples
Case 4	NR	NR	No	NR	Yes	Leash, bio samples
Case 5	NR	NR	No	Yes	Yes	Rope
Case 6	NR	NR	NR	NR	Yes - video	Belt, bio samples
Case 7	NR	NR	No	Yes	Yes	Cord, bio samples
Case 8	NR	NR	No	Yes	Yes	Rope
Case 9	NR	NR	NR	NR	Yes	Rope, shoes, bio samples

	Evidence Kept	PM attended	Weight	Height	Lividity	Rigor mortis
Case 1	NR	Yes	NR	NR	NR	Frozen
Case 2	NR	Yes	NR	NR	NR	NR
Case 3	NR	Yes - only photos of neck though	yes	yes	Yes	Yes
Case 4	Destroyed	Yes - only photos of neck though	NR	NR	NR	NR
Case 5	NR	No Post Mortem	NR	NR	NR	NR
Case 6	NR	Yes	NR	NR	NR	Yes
Case 7	NR	Yes	NR	NR	NR	NR
Case 8	NR	Yes	NR	NR	NR	NR
Case 9	NR	Yes	NR	NR	NR	NR

	Cause of Death	Other Injuries	SOCO or Ident	Suspicious Case	Total Info NR* of 26 traits
Case 1	Asphyxia	No	Ident	No	11
Case 2	Asphyxia	NR	Ident	Yes - due to glove caught in ligature	11
Case 3	Asphyxia	No	Ident	No	8
Case 4	Asphyxia	NR	Ident	Somewhat due to extreme height	14
Case 5	No Post Mortem	No Post Mortem	Ident	No, but also no PM	14
Case 6	Asphyxia	No	Ident	No	14
Case 7	Asphyxia	No	Ident	No	14
Case 8	Asphyxia	No	Ident	No	13
Case 9	Asphyxia	No	Ident	No	16

* not including SOCO/Ident and Suspicious Case columns

OMPPAC SURVEY OF 1999 SUDDEN DEATH HANGING CASES - from Central Region Cases at Barrie TISU

	Type of Hanging	Location of Hanging	Stepping Aids	Suspension point type	Ligature Type
Case 1	Suicidal	Outside	No	Tree limb	3/8" Polypropylene or Nylon Rope
Case 2	Suicidal	Livingroom	chair	Metal Grate/vent	Yellow Nylon Rope
Case 3	Suicidal	Basement	NR	Wood rafters	Bungee cord/tie down
Case 4	Suicidal	Garage	NR	Rafters	Yellow Nylon Rope or Poly
Case 5	Suicidal	Outside	NR	Tree limb	Rope
Case 6	Suicidal	Garage	tire and bathtub	Beam	Blue nylon tie down
Case 7	Suicidal	Bathroom door	No	Door knob and frame	Electrical Cord
	Knot type	**Knot location**	**Hair/clothing caught in ligature**	**Complete or incomplete suspension**	**Suicide Note**
Case 1	NR	R side of neck under ear	NR	Complete 3" from ice/water	No
Case 2	NR	NR	NR	NR	Yes
Case 3	NR	NR	NR	NR	NR
Case 4	NR	NR	NR	NR	NR
Case 5	NR	NR	NR	NR	NR
Case 6	NR	NR	NR	Incomplete	NR
Case 7	NR	NR	NR	Incomplete	NR
	Dirt/dust	**Indentations**	**Fibres**	**Drag marks**	**Signs of struggle**
Case 1	NR	NR	NR	NR	NR
Case 2	NR	NR	NR	NR	NR
Case 3	NR	NR	NR	NR	No
Case 4	NR	NR	NR	NR	NR
Case 5	NR	NR	NR	NR	NR
Case 6	NR	NR	NR	NR	No
Case 7	NR	Yes	Yes	NR	NR
	Measurements taken	**Photographs**	**Main Evidence**	**Evidence Kept**	**PM attended**
Case 1	NR	Yes	Rope, personal effects, blood/urine	Destroyed	Yes
Case 2	Yes	Yes	Rope, wood dowling	Rope held 3 months	NR
Case 3	NR	Yes	Bungee Cord, blood/urine	NR	Yes
Case 4	Yes	Yes	NR	NR	Yes
Case 5	Yes	Yes	Bio samples, Rope, pills	NR	Yes
Case 6	Yes	Yes	Rifle, ammo, rope, bullet, pills	NR	Yes
Case 7	Yes	Yes	Cord, drugs, bio samples	NR	Yes - SOCO
	Weight	**Height**	**Lividity**	**Rigor mortis**	**Cause of Death**
Case 1	Approximated	Yes	NR	Frozen	Asphyxiation
Case 2	NR	NR	NR	NR	Asphyxiation
Case 3	NR	NR	Yes	NR	Asphyxiation
Case 4	NR	NR	Yes	NR	Asphyxiation
Case 5	NR	NR	Yes	NR	Asphyxiation
Case 6	NR	NR	Yes	NR	Gunshot Wound
Case 7	NR	NR	, Yes	Yes	Asphyxiation
	Other Injuries	**SOCO or Ident**	**Suspicious Case**	**Total Info NR* of 26 traits**	
Case 1	Skin abrasion	Ident	Yes - initially victim unidentified	9	
Case 2	No	Ident	No	14	
Case 3	No	Ident	No	14	
Case 4	NR	Soco	No	17	
Case 5	No	Ident	Yes - initially homeless man trespassing arrested	15	
Case 6	Gunshot wound	Ident	No - but is a different scenario due to gunshot wound	12	
Case 7	No	Ident	No	10	
				*not including SOCO/Ident and Suspicious Case columns	

APPENDIX F – SUDDEN DEATH HANGING SCENE INVESTIGATION DATA FORM – CRITERIA FOR EDUCATION

Sudden Death Hanging Scene Investigation Data Form
Criteria for Education

4. Scene Observations	
1. Location of Hanging	Describe: Diagram #:
2. Stepping Aids	Type: Describe:
3. Suspension Point	Type: Describe:
4. Ligature	Type: Describe:
5. Knot Type – neck, suspension	Neck: Describe how tied: Suspension: Describe how tied: Diagram #:
6. Knot Location – neck, suspension	Neck: Describe: Suspension: Describe:
7. Hair/clothing - caught in ligature	**Material Caught:** **Describe:**
8. Complete or Incomplete Suspension	**Complete/Incomplete** Suspension: **Describe:**
9. Suicide Note	Note found: (yes/no) Describe:
10. Dirt or Dust – on victim or disturbed at scene	Describe:
11. Indentation Marks - suspension point	Number of Indentations: Describe: Depth of Main Indentations: Depth of Control Areas selected: (If suspension point is wood) Amount of failure visible: X-section of Indentation examined: Amount of densificatiin: X-section of Control Areas examined: Amount of densificatlon: Diagram #:
12. Fibre direction – suspension point, ligature	Suspension Point: Describe: Ligature: If rope, any snags:
13. Drag Marks – on ground or victim	Describe:

14. Signs of struggle	Describe:
15. Taping - of suspension beam at main indentation, ligature side	Describe: Calculated Area: Calculated Perimeter:
16. Underside of ligature - in contact with suspension beam	Any compression areas: (yes/no) Describe:
17. Collect - suspension beam, ligature, control samples if possible	Describe:
18. Other	Describe:
19. Other	

B. Photographs – other than regular scene and body photos ,

1. Knot type and location – suspension and neck	Photo:
2. Indentations and normal area on suspension	Photo:
3. Fibres – suspension and ligature, and normal areas	Photo:
4. Other	Photo:
5. Other	Photo:

C. Measurements

1. Height of victim	When hanging: At autopsy:
2. Distance from ground to victim's feet	
3. Distance from ground to knot at neck	
4. Distance from knot at neck to Suspension point	
5. Distance from ground to suspension point	To Top of suspension: To Bottom of suspension:
6. Height of stepping aid	
7. Distance from top stepping aid to victim's feet	
8. Dimensions of suspension beam	Length: Width: Height:
9. Other	
10. Other	

D. Evidence Collected at Scene

1. What collected?	
2. Where stored?	
3. Other	
4. Other	

E. Post Mortem Examination

1. Livor mortis	(yes/no) Does correspond to hanging position?
2. Rigor mortis	(yes/no) Does correspond to hanging position?
3. Weight of victim	
4. Other injuries present	(yes/no) Describe:
5. Time since death	**PMI:** Length of time hanging?
6. Cause of death	
7. Measurements	
8. Evidence collected	
9. Photographs taken	
10. Other	
11. Other	

APPENDIX G -DESCRIPTIVE STATISTICS

Area Measurements

Board 1 – Descriptive Statistics of Static Fall Area Measurements

```
MTB > set c1
DATA> 4.55
DATA> 2.74
DATA> 3.3
DATA> 3.57
DATA> 6.214
DATA> 4.873
DATA> 3.387
DATA> 3.27
DATA> 5.01
DATA> 4.745
DATA> 8.508
DATA> 5.27
DATA> 4.08
DATA> 6.446
DATA> 6.602
DATA> end
MTB > describe c1 :
```

Descriptive Statistics

```
Variab1e            N       Mean     Median     TrMean      StDev
SE Mean
c1                 15      4.838      4.745      4.717      1.578
0.408

Variable      Minimum    Maximum         Q1         Q3
c1              2.740      8.508      3.387      6.214
```

Board 1 – Descriptive Statistics of Drag Area Measurements

```
MTB > set c2
DATA> 1.9
DATA> 2.14
DATA> 1.7
DATA> 2.57
DATA> 3.729
DATA> 1.803
DATA> 2.374
DATA> 1.516
DATA> 2.146
DATA> 1.446
DATA> 2.425
DATA> 2.21
DATA> 2.89
DATA> 1.37
DATA> 3.167
DATA> end
MTB > describe c2
```

Descriptive Statistics

```
Variable              N        Mean      Median      TrMean       StDev
SE Mean
c2                   15       2.226       2.146       2.176       0.665
0.172

Variable        Minimum     Maximum          Q1          Q3
c2                1.370       3.729       1.700       2. 570
```

Board 2 – Descriptive Statistics of Static Fall Area Measurements

```
MTB > set c3
DATA> 2.534
DATA> 3.165
DATA> 3.171
DATA> 2.861
DATA> 3.055
DATA> 2.669
DATA> 2.826
DATA> 2.973
DATA> 2.595
DATA> 3.145
DATA> 4.778
DATA> 2.49
DATA> 3.34
DATA> 4.213
DATA> 5.529
DATA> end
MTB > describe c3
```

Descriptive Statistics

```
Variable              N        Mean      Median      TrMean       StDev
SE Mean
c3                   15       3.290       3.055       3.179       0.877
0.226

Variable        Minimum     Maximum          Q1          Q3
c3                2.490       5.529       2.669       3.340
```

Board 2 – Descriptive Statistics of Drag Area Measurements

```
MTB > set c4
DATA> 1.776
DATA> 1.918
DATA> 2.016
DATA> 1.701
DATA> 1.756
DATA> 1.242
DATA> 1.594
DATA> 1.818
DATA> 1.566
DATA> 2.628
```

```
DATA> 1.796
DATA> 1.356
DATA> 1.691
DATA> 2.03
DATA> 2.499
DATA> end
MTB > describe c4
```

Descriptive Statistics

```
Variable            N       Mean     Median     TrMean      StDev
SE Mean
c4                 15     1.8258     1.7760     1.8090     0.3692
0.0953

Variable      Minimum    Maximum         Q1         Q3
c4             1.2420     2.6280     1.5940     2.0160
```

Board 3 – Descriptive Statistics of Static Fall Area Measurements

```
MTB > set c5
DATA> 4.695
DATA> 4.306
DATA> 4.157
DATA> 4.926
DATA> 3.979
DATA> 4.709
DATA> 3.262
DATA> 3.792
DATA> 2.618
DATA> 3.025
DATA> 3.955
DATA> 3.288
DATA> 5.774
DATA> 5.134
DATA> 6.327
DATA> end
MTB > describe c5
```

Descriptive Statistics

```
Variable            N       Mean     Median     TrMean      StDev
SE Mean
c5                 15      4.263      4.157      4.231      1.026
0.265

Variable      Minimum    Maximum         Q1         Q3
c5              2.618      6.327      3.288      4.926
```

Board 3 – Descriptive Statistics of Drag Area Measurements

```
MTB > set c6
DATA> 2.492
DATA> 2.419
```

```
DATA> 2.638
DATA> 3.048
DATA> 2.784
DATA> 2.964
DATA> 2.113
DATA> 2.193
DATA> 2.292
DATA> 1.608
DATA> 2.281
DATA> 3.448
DATA> 2.905
DATA> 3.008
DATA> 2.573
DATA> end
MTB > describe c6
```

Descriptive Statistics

```
Variable          N       Mean     Median     TrMean      StDev
SE Mean
C6               15      2.584      2.573      2.593      0.461
0.119

Variable    Minimum    Maximum         Q1         Q3
C6            1.608      3.448      2.281      2.964
```

Board 4 – Descriptive Statistics of Static Fall Area Measurements

```
MTB > set c7
DATA> 4.299
DATA> 5.999
DATA> 2.843
DATA> 4.977
DATA> 5.244
DATA> 5.764
DATA> 4.663
DATA> 4.246
DATA> 4.869
DATA> 6.321
DATA> 5.017
DATA> 4.162
DATA> 6.342
DATA> 5.93
DATA> 5.563
DATA> end
MTB > describe c7
```

Descriptive Statistics

```
Variable          N       Mean     Median     TrMean      StDev
SE Mean
c7               15      5.083      5.017      5.158      0.957
0.247

Variable    Minimum    Maximum         Q1         Q3
c7            2.843      6.342      4.299      5.930
```

Board 4 – Descriptive Statistics of Drag Area Measurements

```
MTB > set c8
DATA> 2.511
DATA> 2.851
DATA> 1.808
DATA> 2.478
DATA> 2.99
DATA> 2.741
DATA> 2.467
DATA> 2.85
DATA> 2.506
DATA> 2.218
DATA> 2.854
DATA> 2.684
DATA> 3.519
DATA> 2.528
DATA> 3.27
DATA> end
MTB > describe c8
```

Descriptive Statistics

```
Variable           N       Mean     Median     TrMean      StDev
SE Mean
C8                15      2.685      2.684      2.688      0.412
0.106

Variable     Minimum    Maximum         Q1         Q3
C8             1.808      3.519      2.478      2.854
```

Board 5 – Descriptive Statistics of Static Fall Area Measurements

```
MTB > set c9
DATA> 5.658
DATA> 4.689
DATA> 3.837
DATA> 4.853
DATA> 5.829
DATA> 6.754
DATA> 7.264
DATA> 7.275
DATA> 4.897
DATA> 6.556
DATA> 5.677
DATA> 6.163
DATA> 7.763
DATA> 7.156
DATA> 7.66
DATA> end
MTB > describe c9
```

Descriptive Statistics

```
Variable            N        Mean      Median      TrMean       StDev
SE Mean
c9                 15       6.135       6.163       6.187       1.202
0.310

Variable      Minimum     Maximum          Q1          Q3
c9              3.837       7.763       4.897       7.264
```

Board 5 – Descriptive Statistics of Drag Area Measurements

```
MTB > set c10
DATA> 2.79
DATA> 3.008
DATA> 2.883
DATA> 2.735
DATA> 3.561
DATA> 4.368
DATA> 3.828
DATA> 4.263
DATA> 2.595
DATA> 3.092
DATA> 4.661
DATA> 3.656
DATA> 3.583
DATA> 4.848
DATA> 4.318
DATA> end
MTB > describe c10
```

Descriptive Statistics

```
Variable            N        Mean      Median      TrMean       StDev
SE Mean
c10                15       3.613       3.583       3.596       0.747
0.193

Variable      Minimum     Maximum          Q1          Q3
c10             2.595       4.848       2.883       4.318
```

Board 6 – Descriptive Statistics of Static Fall Area Measurements

```
MTB > set cll
DATA> 3.641
DATA> 3.779
DATA> 4.534
DATA> 4.438
DATA> 5.167
DATA> 4.512
DATA> 3.426
DATA> 4.248
DATA> 4.285
DATA> 3.784
```

```
DATA> 3.542
DATA> 4.318
DATA> 5.269
DATA> 4.632
DATA> 5.733
DATA> end
MTB > describe cll
```

Descriptive Statistics

```
Variable            N       Mean     Median     TrMean      StDev
SE Mean
c11                15      4.354      4.318      4.319      0.668
0.172

Variable      Minimum    Maximum         Q1         Q3
c11             3.426      5.733      3.779      4.632
```

Board 6 – Descriptive Statistics of Drag Area Measurements

```
MTB > set c12
DATA> 2.329
DATA> 4.116
DATA> 4.404
DATA> 3.555
DATA> 3.988
DATA> 3.858
DATA> 2.007
DATA> 4.241
DATA> 3.319
DATA> 3.553
DATA> 2.597
DATA> 3.516
DATA> 3.85
DATA> 3.542
DATA> 2.903
DATA> end
MTB > describe c12
```

Descriptive Statistics

```
Variable            N       Mean     Median     TrMean      StDev
SE Mean
c12                15     3 .452      3.553     3 .490      0.708
0.183

Variable      Minimum    Maximum         Q1         Q3
c12             2.007      4.404      2.903      3.988
```

Board 7 – Descriptive Statistics of Static Fall Area Measurements

```
MTB > set c13
DATA> 6.181
DATA> 4.726
```

```
DATA> 3.066
DATA> 3.984
DATA> 4.044
DATA> 3.73
DATA> 4.992
DATA> 4.668
DATA, 4.169
DATA> 4.561
DATA> 3.411
DATA> 3.022
DATA> 5.205
DATA> 4.503
DATA> 3.938
DATA> end
MTB > describe c13
```

Descriptive Statistics

```
Variable              N        Mean      Median      TrMean        StDev
SE Mean
C13                  15       4.280       4.169       4.231        0.838
0.216

Variable        Minimum     Maximum          Q1          Q3
C13               3.022       6.181       3.730       4.726
```

Board 7 – Descriptive Statistics of Drag Area Measurements

```
MTB > set c14
DATA> 3.634
DATA, 2.747
DATA> 1.984
DATA> 2.563
DATA> 2.77
DATA> 2.791
DATA> 3.516
DATA> 2.63
DATA> 3.28
DATA> 2.834
DATA> 2.684
DATA> 3.105
DATA> 3.206
DATA> 2.584
DATA> 2.323
DATA> end
MTB > describe c14
```

Descriptive Statistics

```
Variable              N        Mean      Median      TrMean        StDev
SE Mean
C14                  15       2.843       2.770       2.849        0.440
0.114

Variable        Minimum     Maximum          Q1          Q3
C14               1.984       3.634       2.584       3.206
```

Board 8 – Descriptive Statistics of Static Fall Area Measurements

```
MTB > set c15
DATA> 4.536
DATA> 4.571
DATA> 4.627
DATA> 5.64
DATA> 5.58
DATA> 4.112
DATA> 4.904
DATA> 5.421
DATA> 4.285
DATA> end
MTB > describe c15
```

Descriptive Statistics

```
Variable            N       Mean     Median     TrMean      StDev
SE Mean
C15                 9      4.853      4.627      4.853      0.567
0.189

Variable      Minimum    Maximum         Q1         Q3
C15             4.112      5.640      4.410      5.500
```

Board 8 – Descriptive Statistics of Drag Area Measurements

```
MTB > set c16
DATA> 2.51
DATA> 3.548
DATA> 2.223
DATA> 3.984
DATA> 3.479
DATA> 2.772
DATA> 2.518
DATA> 2.535
DATA> 3.319
DATA> end
MTB > describe c16
```

Descriptive Statistics

```
Variable            N       Mean     Median     TrMean      StDev
SE Mean
C16                 9      2.988      2.772      2.988      0.606
0.202

Variable      Minimum    Maximum         Q1         Q3
c16             2.223      3.984      2.514      3.513
```

Perimeter Measurements

Board 1 – Descriptive Statistics of Static Fall Perimeter Measurements

```
MTB > set c17
DATA> 10.25
DATA> 8.59
DATA> 8.1
DATA> 8.58
DATA> 11.732
DATA> 11.836
DATA> 12.088
DATA> 9.173
DATA> 12.098
DATA> 11.347
DATA> 15.288
DATA> 12.85
DATA> 11.62
DATA> 13.983
DATA> 12.953
DATA, end
MTB > describe c17
```

Descriptive Statistics

```
Variable            N       Mean     Median     TrMean      StDev
SE Mean
C17                15     11.366     11.732     11.315      2.081
0.537

Variable      Minimum    Maximum         Q1         Q3
C17             8.100     15.288      9.173     12.850
```

Board 1 – Descriptive Statistics of Drag Perimeter Measurements

```
MTB > set c18
DATA> 6.02
DATA> 7.32
DATA, 6.2
DATA, 8.61
DATA> 9.106
DATA> 6.758
DATA> 7.963
DATA> 5.657
DATA, 7.033
DATA> 6.221
DATA> 7.569
DATA, 7.16
DATA> 7.47
DATA> 6.143
DATA> 8.842
DATA> end
MTB > describe c18
```

Descriptive Statistics

```
Variab1e            N        Mean      Median      TrMean       StDev
SE Mean
C18                15       7.205       7.160       7.178       1.076
0.278

Variable      Minimum     Maximum          Q1          Q3
C18             5.657       9.106       6.200       7.963
```

Board **2** – Descriptive Statistics of Static Fall Perimeter Measurements

```
MTB > set c19
DATA> 8.883
DATA> 9.27
DATA> 10.172
DATA> 9.108
DATA> 9.227
DATA> 8.479
DATA> 8.811
DATA> 9.062
DATA> 9.46
DATA> 10.684
DATA> 12.23
DATA> 9.242
DATA> 9.232
DATA> 11.247
DATA> 12.855
DATA> end
MTB > describe c19
```

Descriptive Statistics

```
Variable            N        Mean      Median      TrMean       StDev
SE Mean
c19                15       9.864       9.242       9.741       1.313
0.339

Variable      Minimum     Maximum          Q1          Q3
c19             8.479      12.855       9.062      10.684
```

Board 2 – Descriptive Statistics of Drag Perimeter Measurements

```
MTB > set c20
DATA> 5.79
DATA> 6.249
DATA> 6.458
DATA> 5.595
DATA> 5.952
DATA> 5.143
DATA> 5.612
DATA> 6.295
DATA> 11.913
DATA> 7.224
DATA> 5.867
DATA> 5.551
```

```
DATA> 6.172
DATA> 5.969
DATA> 6.751
DATA> end
MTB > describe c20
```

Descriptive Statistics

```
Variable            N       Mean      Median      TrMean       StDev
SE Mean
c20                15      6.436       5.969       6.114       1.601
0.413

Variable      Minimum    Maximum          Q1          Q3
c20             5.143     11.913       5.612       6.458
```

Board 3 – Descriptive Statistics of Static Fall Perimeter Measurements

```
MTB > set c21
DATA> 10.657
DATA> 8.797
DATA> 10.193
DATA> 9.112
DATA> 8.676
DATA> 10.016
DATA> 8.93
DATA> 8,996
DATA> 6.971
DATA> 7.722
DATA> 8.885
DATA> 7.779
DATA> 10.769
DATA> 10.69
DATA> 14.664
DATA> end
MTB > describe c21
```

Descriptive Statistics

```
Variable            N       Mean      Median      TrMean       StDev
SE Mean
c21                15      9.524       8.996       9.325       1.824
0.471

Variable      Minimum    Maximum          Q1          Q3
c21             6.971     14.664       8.676      10.657
```

Board 3 – Descriptive Statistics of Drag Perimeter Measurements

```
MTB > set c22
DATA> 6.302
DATA> 6.013
DATA> 7.085
DATA> 7.947
DATA> 7.327
DATA> 7.4
DATA> 6.52
```

```
DATA> 6.939
DATA> 6.228
DATA> 6.739
DATA> 7.192
DATA> 8.056
DATA> 7.216
DATA> 7.667
DATA> 8.656
DATA> end
MTB > describe c22
```

Descriptive Statistics

```
Variable            N       Mean     Median     TrMean      StDev
SE Mean
c22                15      7.152      7.192      7.124      0.735
0.190

Variable      Minimum    Maximum         Q1         Q3
c22             6.013      8.656      6.520      7.667
```

Board 4 – Descriptive Statistics of Static Fall Perimeter Measurements

```
MTB > set c23
DATA> 9.766
DATA> 11.409
DATA, 8.064
DATA> 11.45
DATA> 12.464
DATA> 12.713
DATA, 10.941
DATA> 1.815
DATA> 11.566
DATA> 12.742
DATA> 12.389
DATA> 10.12
DATA> 12.1
DATA> 13.605
DATA> 11.756
DATA> end
MTB > describe c23
```

Descriptive Statistics

```
Variable            N       Mean     Median     TrMean      StDev
SE Mean
C23                15     10.860     11.566     11.345      2.857
0.738

Variable      Minimum    Maximum         Q1         Q3
C23             1.815     13.605     10.120     12.464
```

Board 4 – Descriptive Statistics of Drag Perimeter Measurements

```
MTB > set c24
DATA> 7.352
DATA> 7.983
DATA> 5.394
DATA> 6.448
DATA> 7.515
DATA> 7.635
DATA> 7.32
DATA> 7.173
DATA> 6.666
DATA> 6.662
DATA> 7.707
DATA> 7.395
DATA> 8.21
DATA> 6.929
DATA> 7.548
DATA> end
MTB > describe c24
```

Descriptive Statistics

```
Variable            N       Mean     Median     TrMean      StDev
SE Mean
C24                15      7.196      7.352      7.256      0.700
0.181

Variable      Minimum    Maximum         Q1         Q3
C24             5.394      8.210      6.666      7.635
```

Board 5 – Descriptive Statistics of Static Fall Perimeter Measurements

```
MTB > set c25
DATA> 12.628
DATA> 12.794
DATA> 11.17
DATA> 12.856
DATA> 13.041
DATA> 12.961
DATA> 13.769
DATA> 14.418
DATA> 11.178
DATA> 13.853
DATA> 12.37
DATA> 15.263
DATA> 14.265
DATA> 13.088
DATA> 14.041
DATA> end
MTB > describe c25
```

Descriptive Statistics

```
Variable            N      Mean    Median    TrMean     StDev
SE Mean
C25                15    13.180    13.041    13.174     1.132
0.292

Variable      Minimum   Maximum        Q1        Q3
C25            11.170    15.263    12.628    14.041
```

Board 5 – Descriptive Statistics of Drag Perimeter Measurements

```
MTB > set c26
DATA> 7.847
DATA> 8.114
DATA> 7.782
DATA> 7.473
DATA> 9.113
DATA> 9.907
DATA> 8.586
DATA> 10.022
DATA> 7.618
DATA> 10.0625
DATA> 10.409
DATA> 8.762
DATA> 8.281
DATA> 9.424
DATA> 9.863
DATA> end
MTB > describe c26
```

Descriptive Statistics

```
Variable            N      Mean    Median    TrMean     StDev
SE Mean
C26                15     8.884     8.762     8.876     1.011
0.261

Variable      Minimum   Maximum        Q1        Q3
C26             7.473    10.409     7.847     9.907
```

Board **6 –** Descriptive Statistics of Static Fall Perimeter Measurements

```
MTB > set c27
DATA> 9.593
DATA> 9.261
DATA> 10.983
DATA> 10.428
DATA> 12.069
DATA> 11.418
DATA> 9.504
DATA> 10.453
DATA> 10.983
DATA> 9.933
DATA> 9.813
DATA> 10.313
```

```
DATA> 11.426
DATA> 10.82
DATA> 12.124
DATA> end
MTB > describe c27
```

Descriptive Statistics

```
Variable          N      Mean    Median    TrMean     StDev
SE Mean
C27              15    10.608    10.453    10.595     0.902
0.233

Variable    Minimum   Maximum        Q1        Q3
C27           9.261    12.124     9.813    11.418
```

Board **6** – Descriptive Statistics of Drag Perimeter Measurements

```
MTB > set c28
DATA> 6.758
DATA> 9.004
DATA> 9.728
DATA> 8.175
DATA> 9.772
DATA> 8.881
DATA> 6.849
DATA> 12.844
DATA> 8.019
DATA> 8.602
DATA> 7.308
DATA> 8.8
DATA> 8.981
DATA> 8.529
DATA> 7.451
DATA> end
MTB > describe c28
```

Descriptive Statistics

```
Variable          N      Mean    Median    TrMean     StDev
SE Mean
C28              15     8.647     8.602     8.469     1.489
0.384

Variable    Minimum   Maximum        Q1        Q3
C28           6.758    12.844     7.451     9.004
```

Board 7 – Descriptive Statistics of Static Fall Perimeter Measurements

```
MTB > set c29
DATA> 12.684
DATA> 12.133
DATA> 9.562
DATA> 10.67
DATA> 11.027
DATA> 10.847
```

```
DATA> 12.227
DATA> 11.079
DATA> 10.346
DATA> 11.5
DATA> 9.331
DATA> 9.041
DATA> 9.041
DATA> 11.129
DATA,  11.3
DATA> end
MTB > describe c29
```

Descriptive Statistics

```
Variable            N        Mean      Median      TrMean       StDev
SE Mean
C29                15      10.794      11.027      10.784       1.148
0.296

Variable      Minimum     Maximum          Q1          Q3
C29             9.041      12.684       9.562      11.500
```

Board 7 – Descriptive Statistics of Drag Perimeter Measurements

```
MTB > set c30
DATA> 9.119
DATA> 7.702
DATA> 6.769
DATA> 7.359
DATA> 7.101
DATA> 7.931
DATA> 8.113
DATA> 6.994
DATA> 7.953
DATA> 7.854
DATA> 7.486
DATA> 8.729
DATA> 8.253
DATA> 7.445
DATA> 6.835
DATA> end
MTB > describe c30
```

Descriptive Statistics

```
Variable            N        Mean      Median      TrMean       StDev
SE Mean
C30                15       7.710       7.702       7.673       0.675
0.174

Variable      Minimum     Maximum          Q1          Q3
C30             6.769       9.119       7.101       8.113
```

Board 8 – Descriptive Statistics of Static Fall Perimeter Measurements

```
MTB > set c31
DATA> 13.055
DATA> 11.314
DATA> 11.425
DATA> 11.9
DATA> 11.561
DATA> 10.846
DATA> 12.642
DATA> 11.447
DATA> 10.983
DATA> end
MTB > describe c31
```

Descriptive Statistics

```
Variable            N       Mean     Median     TrMean      StDev
SE Mean
C31                 9     11.686     11.447     11.686      0.734
0.245

Variable      Minimum    Maximum         Q1         Q3
C31            10.846     13.055     11.149     12.271
```

Board 8 – Descriptive Statistics of Drag Perimeter Measurements

```
MTB > set c32
DATA> 7.252
DATA> 8.209
DATA> 7.139
DATA> 9.181
DATA> 8.054
DATA> 7.769
DATA> 7.441
DATA> 8.396
DATA> 8.019
DATA> end
MTB > describe c32
```

Descriptive Statistics

```
Variable            N       Mean     Medi n     TrMean      StDev
SE Mean
C32                 9      7.940      8.019      7.940      0.636
0.212

Variable      Minimum    Maximum         Q1         Q3
C32             7.139      9.181      7.347      8.303
```

Control Measurements

```
Worksheet size: 100000 cells

MTB > set cl #board 1-ligature side#
DATA> 5.88 5.88 6.22 6.16  6.02 6.39 6.46 6.32 5.98 5.96 6.15 6.27 6.30 6.01 6.04
DATA> end
MTB > describe cl
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
c1	15	6.1360	6.1500	6.1308	0.1853	0.0479

Variable	Minimum	Maximum	Q1	Q3
c1	5.8800	6.4600	5.9800	6.3000

```
MTB > set c2 #board 1-opposite side#
DATA> 6.11 5.89 5.81 5.80 5.60 5.75 5.62 5.68 5.59 5.94 5.85 5.55 5.63 5.93 6.00
DATA> end
MTB > describe c2
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
c2	15	5.7833	5.8000	5.7762	0.1699	0.0439

Variable	Minimum	Maximum	Q1	Q3
c2	5.5500	6.1100	5.6200	5.9300

```
MTB > set c3 #board 2-ligature side#
DATA> 5.62 5.92 6.21 6.02 5.93 6.16 6.13 6.13 6.31 6.10 6.25 6.45 6.33 6.22 5.89
DATA> end
MTB > describe c3
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
c3	15	6.1113	6.1300	6.1231	0.2095	0.0541

Variable	Minimum	Maximum	Q1	Q3
c3	5.6200	6.4500	5.9300	6.2500

```
MTB > set c4 #board 2-opposite side#
DATA> 6.51 6.39 6.42 6.33 6.11 6.34 6.29 6.37 6.33 6.25 6.07 5.98 6.35 6.19 6.19
DATA> end
MTB > describe c4
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
c4	15	6.2747	6.3300	6.2792	0.1429	0.0369

Var iab1e	Minimum	Maximum	Q1	Q3
c4	5.9800	6.5100	6.1900	6.3700

```
MTB > set c5 #board 3-ligature side#
DATA> 6.00 5.84 5.81 6.01 6.01 5.96 5.90 5.91 5.86 5.85 6.00 6.04 6.00 5.95 6.04
DATA> end
MTB > describe c5
```

Descriptive Statistics

```
Variable              N       Mean     Median     TrMean      StDev    SE Mean
c5                   15     5.9453     5.9600     5.9485     0.0777     0.0201

Variable        Minimum    Maximum         Q1         43
c5               5.8100     6.0400     5.8600     6.0100

MTB > set c6 #board 3-opposite side#
DATA> 6.07 5.95 5.78 6.24 5.95 6.00 6.04 6.02 5.85 5.98 6.43 6.37 6.46 6.16 6.21
DATA> end
MTB > describe c6
```

Descriptive Statistics

```
Variable              N       Mean     Median     TrMean      StDev    SE Mean
C6                   15     6.1007     6.0400     6.0977     0.2056     0.0531

Variable'       Minimum    Maximum         Q1         43
C6               5.7800     6.4600     5.9500     6.2400

MTB>  set c7 #board4-ligature side#
DATA> 5.53 4.94 5.82 5.51  5.36 5.48 5.85 5.40 5.64 5.46 5.62 5.50 5.61 5.69 5.68
DATA> end
MTB > describe c7
```

Descriptive Statistics

```
Variab1e              N       Mean     Median     TrMean      StDev    SE Mean
c7                   15     5.5393     5.5300     5.5615     0.2175     0.0562

Variable        Minimum    Maximum         Q1         Q3
c7               4.9400     5.8500     5.4600     5.6800

MTB > set c8 #board 4-opposite side#
DATA> 5.42 5.60 5.40 5.51 5.60 5.58 5.56 5.68 5.89 5.48 5.33 5.43 5.70 5.76 5.44
DATA> end
MTB > describe c8
```

Descriptive Statistics

```
Variable              N       Mean     Median     TrMean      StDev    SE Mean
C8                   15     5.5587     5.5600     5.5508     0.1523     0.0393

Variable        Minimum    Maximum         Q1         Q3
C8               5.3300     5.8900     5.4300     5.6800

MTB > sec c9 #board 5-ligature side#
DATA> 6.27 6.10 6.10 6.17 6.18 5.78 5.75 5.79 5.92 5.99 6.22 6.34 6.36 6.34 6.09
DATA> end
MTB > describe c9
```

Descriptive Statistics

```
Variable              N       Mean     Median     TrMean      StDev    SE Mean
c9                   15     6.0933     6.1000     6.0992     0.2074     0.0536

Variable        Minimum    Maximum         Q1         Q3
c9               5.7500     6.3600     5.9200     6.2700
```

```
MTB > set c10 #board 5-opposite side#
DATA> 6.17 6.12 6.16 6.27 6.18 6.39 6.11 6.43 6.12 6.17 6.28 6.21 6.08 6.14 6.03
DATA> end
MTB > describe c10
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
c10	15	6.1907	6.1700	6.1846	0.1104	0.0285

Variable	Minimum	Maximum	Q1	Q3
c10	6.0300	6.4300	6.1200	6.2700

```
MTB > set cll #board 6-ligature side#
DATA> 6.66 6.61 6.76 6.83 6.73 6.62 6.53 6.66 6.76 6.59 6.88 6.75 6.88 6.76 6.86
DATA> end
MTB > describe cll
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
c11	15 .	6.7253	6.7500	6.7285	0.1104	0.0285

Variable	Minimum	Maximum	Q1	Q3
c11	6.5300	6.8800	6.6200	6.8300

```
MTB > set c12 #board 6-opposite side#
DATA> 6.64 6.84 6.63 6.56 6.54 6.57 6.40 6.52 6.47 6.28 6.50 6.62 6.51 6.60 6.60
DATA> end
MTB > describe c12
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
c12	15	6.5520	6.5600	6.5508	0.1242	0.0321

Variable	Minimum	Maximum	Q1	Q3
c12	6.2800	6.8400	6.5000	6.6200

```
MTB > set c13 #board 7-ligature side#
DATA> 6.27 6.58 6.56 6.55 6.37 6.49 6.37 6.17 6.15 6.29 6.41 6.24 6.19 6.36 6.34
DATA> end
MTB > describe c13
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
C13	15	6.3560	6.3600	6.3546	0.1416	0.0366

Variable	Minimum	Maximum	Q1	Q3
C13	6.1500	6.5800	6.2400	6.4900

```
MTB > set cl4 #board 7-opposite side#

DATA> 6.38 6.42 6.19 6.61 6.27 6.68 6.30 6.30 6.60 6.57 6.51 6.61 6.63 6.63 6.38
DATA> end
MTB > describe c14
```

Descriptive Statistics

```
Variable            N      Mean    Median    TrMean     StDev   SE Mean
C14                15    6.4720    6.5100    6.4777    0.1599    0.0413

Variable      Minimum   Maximum        Q1        Q3
C14            6.1900    6.6800    6.3000    6.6100

MTB > set c15 #board 8-ligature side#
DATA> 6.19 6.05 6.00 6.01 6.21 6.29 5.61 6.09 6.15 6.04 6.18 6.25 5.87 6.26 6.02
DATA> end
MTB > describe c15
```

Descriptive Statistics

```
Variable            N      Mean    Median    TrMean     StDev   SE Mean
C15                15    6.0813    6.0900    6.1015    0.1756    0.0453

Variable      Minimum   Maximum        Q1        Q3
C15            5.6100    6.2900    6.0100    6.2100

MTB > set c16 #board 8-opposite side#
DATA> 6.25 5.91 6.00 6.00 6.11 5.92 6.46 6.25 6.14 5.98 5.98 6.24 5.98 6.24 5.84
DATA> end
MTB > describe c16
```

Descriptive Statistics

```
Variable            N      Mean    Median    TrMean     StDev   SE Mean
C16                15    6.0867    6.0000    6.0769    0.1716    0.0443

Variable      Minimum   Maximum        Q1        Q3
C16            5.8400    6.4600    5.9800    6.2400

MTB > set c17 #board 9-ligature side#
DATA> 6.09 5.87 5.57 5.52 5.53 5.63 5.68 5.75 5.69 5.74 5.89 5.75 5.73 5.77 5.66
DATA> end
MTB > describe c17
```

Descriptive Statistics

```
Variable            N      Mean    Median    TrMean     StDev   SE Mean
C17                15    5.7247    5.7300    5.7123    0.1477    0.0381

Variable      Minimum   Maximum        Q1        Q3
C17            5.5200    6.0900    5.6300    5.7700

MTB > set c18 #board 9-opposite side#
DATA> 5.86 5.68 5.68 5.73 5.74 5.55 5.82 5.85 5.47 5.47 5.52 5.74 5.83 5.80 5.84
DATA> end
MTB > describe c18
```

Descriptive Statistics

```
Variable            N      Mean    Median    TrMean     StDev   SE Mean
C18                15    5.7053    5.7400    5.7115    0.1399    0.0361

Variable      Minimum   Maximum        Q1        Q3
C18            5.4700    5.8600    5.5500    5.8300

MTB > set c19 #board 10-ligature side#
```

```
DATA> 5.55 5.48 5.41 5.28 5.24 5.51 5.34 5.60 5.51 5.39 5.48 5.22 .50 5.45 5.50
DATA> end
MTB > describe c19
```

Descriptive Statistics

```
Variable            N       Mean     Median     TrMean      StDev    SE Mean
c19                15      5.097      5.450      5.412      1.277      0.330

Variable      Minimum    Maximum         Q1         Q3
c19             0.500      5.600      5.280      5.510

MTB > set c20 #board 10-opposite side#
DATA> 5.58 5.75 5.67 5.81 5.57 5.52 5.48 5.27 5.33 5.52 5.41 5.69 5.45 5.57 5.27
DATA> end
MTB > describe c20
```

Descriptive Statistics

```
Variable            N       Mean     Median     TrMean      StDev    SE Mean
c20                15     5.5260     5.5200     5.5238     0.1639     0.0423

Variable      Minimum    Maximum         Q1         Q3
c20            5.2700     5.8100     5.4100     5.6700

MTB > set c21 #board 11-ligature side#
DATA> 5.83 5.52 5.42 5.52 5.47 5.47 5.29 5.36 5.38 5.39 5.32 5.30 5.31 5.38 5.25
DATA> end
MTB > describe c21
```

Descriptive Statistics

```
Variable            N       Mean     Median     TrMean      StDev    SE Mean
c21                15     5.4140     5.3800     5.3946     0.1421     0.0367

Variable      Minimum    Maximum         Q1         Q3
c21            5.2500     5.8300     5.3100     5.4700

MTB > set c22 #board 11-opposite side#
DATA> 6.01 5.28 5.38 5.25 5.25 5.29 5.29 5.37 5.24 5.32 5.39 5.74 5.28 5.56 5.34
DATA> end
MTB > describe c22
```

Descriptive Statistics

```
Variable            N       Mean     Median     TrMean      StDev    SE Mean
c22                15     5.3993     5.3200     5.3646     0.2152     0.0556

Variable .    Minimum    Maximum         Q1         Q3
c22            5.2400     6.0100     5.2800     5.3900

MTB > set c23 #board 12-ligature side#
DATA> 5.47 5.59 5.75 5.89 5.79 5.68 5.64 5.37 5.38 5.73 5.38 5.57 5.61 5.93 5.51
DATA> end
MTB > describe c23
```

Descriptive Statistics

```
Variable            N       Mean     Median     TrMean      StDev    SE Mean
```

```
C23                 15     5.6193     5.6100     5.6146     0.1786     0.0461

Variable       Minimum    Maximum         Q1         Q3
C23             5.3700     5.9300     5.4700     5.7500

MTB > set c24 #board 12-opposite side#
DATA> 5.83 5.88 5.70 5.47 5.65 5.66 5.69 5.77 5.68 5.70 5.75 5.71 5.73 5.74 5.82
DATA> end
MTB > describe c24
```

Descriptive Statistics

```
Variable             N       Mean     Median     TrMean      StDev    SE Mean
C24                 15     5.7187     5.7100     5.7254     0.0949     0.0245

Variable       Minimum    Maximum         Q1         Q3
C24             5.4700     5.8800     5.6800     5.7700

MTB > set c25 #board 13-ligature side#
DATA> 5.79 5.91 5.69 5.57 5.70 5.87 6.00 5.76 5.96 5.82 6.04 6.08 6.12 6.00 5.99
DATA> end
MTB > describe c25
```

Descriptive Statistics

```
Variable             N       Mean     Median     TrMean      StDev    SE Mean
C25                 15     5.8867     5.9100     5.8931     0.1607     0.0415

Variable       Minimum    Maximum         Q1         Q3
C25             5.5700     6.1200     5.7600     6.0000

MTB > set c26 #board 13-opposite side#
DATA> 5.67 6.10 5.87 5.87 5.90 5.86 5.78 5.95 5.70 5.88 5.94 6.12 5.75 5.95 5.97
DATA> end
MTB > describe c26
```

Descriptive Statistics

```
Variable             N       Mean     Median     TrMean      StDev    SE Mean
C26                 15     5.8873     5.8800     5.8862     0.1285     0.0332

Variable       Minimum    Maximum         Q1         Q3
C26             5.6700     6.1200     5.7800     5.9500

MTB >
```

Descriptive Statistics of Indentations

Board 1-Ligature side – Static Falls

```
1)  MTB > set c1
DATA> 8.83  8.84  8.91  9.14  9.18  9.19  7.77  7.81  7.77  9.27  9.32  9.32  9.41  9.43  9.44  8.7  8.73
8.68  9.21  9.2  9.16  9.41  9.37  9.37  8.88  8.86  8.91  9.7  9.68  9.6

DATA> end
MTB > describe cl
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
C1	30	9.0363	9.1850	9.0835	0.5102	0 0931

Variable	Minimum	Maximum	Q1	Q3
c1	7.7700	9.7000	8.8375	9.3800

Board 1 – Opposite Side – Static Falls

```
MTB > set c2
DATA> 6.3  6.25  6 31 6.69  6.48  6.45  6.75  6.71  6.81  6.93  6.94  7.04  6.95  6.96  6.94  6.55  6.46
6.52  7.01  7.09  7 02 6.9  6.96  6.91 6.84  6.82  6.8
DATA> 6.95  6.98  6.93
DATA> end
MTB > describe c2
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
c2	30	6.7750	6.8700	6.7912	0.2448	0.0447

Variable	Minimum	Maximum	Q1	Q3
c2	6.2500	7.0900	6.5425	6.9525

Board 1 – Ligature Side – Drags

```
MTB > set c3
DATA> 6.91    6.87    6.93
DATA> 6.85    6.99    6.92
DATA> 6.28    6.27    6.26
DATA> 6.36    6.32    6.27
DATA> 6.37    6.47    6.38
DATA>         6.53    6.45
DATA>         6.65    6.63
DATA>         6.88    6.92
DATA> 6.78    6.83    6.81
DATA> 6.37    6.3     6.3
DATA> end

* NOTE  * Text found in data line.

MTB > describe c3
```

Descriptive Statistics

```
Variable              N       Mean     Median     TrMean      StDev    SE Mean
c3                   30     6.5980     6.5800     6.5958     0.2599     0.0474

Variable        Minimum    Maximum         Q1         Q3
c3               6.2600     6.9900     6.3500     6.8725
```

Board 1 – Opposite Side – Drags

```
MTB > set c4
DATA> 5.64     5.69    6.71
DATA> 5.67     5.63    5.65
DATA> 5.84     5.9     5.87
DATA> 5.94     5.96    5.91
DATA> 5.83     5.88    5.82
DATA> 5.82     5.86    5.89
DATA> 6.15     6.1     6.13
DATA> 6.02.    6.01    5.98
DATA> 5.99     5.93    6
DATA> 6.28'    6.31    6.24
DATA> end

* NOTE  * Text found in data line.

MTB > describe c4
```

Descriptive Statistics

```
Variable              N       Mean     Median     TrMean      StDev    SE Mean
c4                   30     5.9550     5.9200     5.9369     0.2297     0.0419

Variable        Minimum    Maximum         Q1         Q3
c4               5.6300     6.7100     5.8275     6.0400
```

Board 2 – Ligature side – Static Falls

```
MTB > set c5
DATA> 8.12     8.18    8.2
DATA> 7.96     7.99    7.93
DATA> 8.39     8.4     8.35
DATA> 9.14     9.17    9.19
DATA> 7.81     7.89    7.85
DATA> 8.67     8.71    8.7
DATA> 8.56     8.61    8.56
DATA> 8.44     8.53    8.52
DATA> 7.91     8.01    7.94
DATA> 8.48   . 8.51    8.5
DATA> 9.12     9.1     9.17
DATA> 8.83     8.82    8.75
DATA> 7.53     7.54    7.62
DATA> end

* NOTE  * Text found in data line

MTB > describe c5
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
c5	39	8.4026	8.4800	8.4077	0.4767	0.0763

Variable	Minimum	Maximum	Q1	43
c5	7.5300	9.1900	7.9600	8.7100

Board 2 - Opposite side - Static Falls

```
MTB > set c6
DATA> 8.13    8.14   8.1
DATA> 7.71    7.74   7.74
DATA> 7.98    8.01   8.05
DATA> 8.39    8.44   8.54
DATA> 7.56    7.6    7.46
DATA> 8.67    8.77   8.72
DATA> 8.55    8.6    8.55
DATA> 8.33    8.35   8.36
DATA> 8.75    8.85   8.7
DATA> 8.18    8.23   8.16
DATA> 8.09    8.05   8.05
DATA> 7.52    7.58   7.52
DATA> 7.86    7.94   7.94
DATA> end

* NOTE  * Text found in data line.

MTB > describe c6
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
C6	39	8.1515	8.1300	8.1517	0.4008	0.0642

Variable	Minimum	Maximum	Q1	43
C6	7.4600	8.8500	7.8600	8.5400

Board 2 - Ligature Side - Drags

```
MTB > set c7
DATA> 6.81    6.8    6.8
DATA> 6.99    6.87   6.93
DATA> 6.58    6.56   6.59
DATA> 6.46    6.44   6.41
DATA> 6.32    6.76   6.72
DATA> 6.89    6.91   6.89
DATA> 7.28    7.26   7.2
DATA> 6.99    6.98   6.92
DATA> 6.8     6.83   6.78
DATA> 7.06    7.05   7.07
DATA> 7.14    7.09   7.06
DATA> 7.03    7.07   6.97
DATA> 7.04    7.08   7.04
DATA> 6.81    6.82   6.84
DATA> 6.65    6.69   6.69
DATA> end

  NOTE  * Text found in data line.

MTB > describe
```

Descriptive Statistics

```
Variable          N      Mean    Median    TrMean     StDev   SE Mean
c7               45    6.8749    6.8900    6.8776    0.2105    0.0314

Variable    Minimum   Maximum        Q1        Q3
c7           6.4100    7.2800    6.7400    7.0450
```

Board 2 – Opposite side – Drags

```
MTB > set c8
DATA> 6.86    6.87   6.88
DATA> 7.1 7.13   7.09
DATA> 6.99    7.03   7.05
DATA> 6.97    6.97   6.94
DATA> 7.1 7.03   7.1
DATA> 7.16    7.19   7.1
DATA> 6.97    6.92   6.9
DATA> 7.08    7.08   7.13
DATA> 7.06    7.03   7.04
DATA> 7.15    7.1    7.14
DATA> 6.95    6.98   6.99
DATA> 6.87    6.91   6.88
DATA> 7.31    7.34   7.27
DATA> 7.02    7.11   7
DATA> 7.26    7.29   7.28
DATA> end

* NOTE  * Text found in data line.

MTB > describe c8
```

Descriptive Statistics

```
Variab1e          N      Mean    Median    TrMean     StDev   SE Mean
C8               45    7.0582    7.0500    7.0546    0.1270    0.0189

Variable    Minimum   Maximum        Q1
C8           6.8600    7.3400    6.9700    7.1300
```

Board 3 - Ligature side - Static Falls

```
MTB > set c9
DATA> 7.51    7.54   7.55
DATA> 7.45    7.49   7.48
DATA> 8.66    8.67   8.71
DATA> 8.38    8.37   8.34
DATA> 9.17    9.11   9.14
DATA> 8.28    8.27   8.28
DATA> 8.23    8.25   8.2
DATA> 8.67    8.63   8.71
DATA> 7.8    7.91   7.87
DATA> 8.3    8.31   8.32
DATA> 8.89    8.89   8.84
DATA> 8.1     8.1    8.09
DATA> 8.62    8.64   8.67
DATA> 8.46    8.46   8.44
DATA> 8.98    8.99   9.02
DATA> end
```

```
* NOTE   * Text found in data line.

MTB > describe c9
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
c9	45	8.3731	8.3700	8.3793	0.4804	0.0716

Variable	Minimum	Maximum	Ql	Q3
c9	7.4500	9.1700	8.1000	8.6900

Board 3 – Opposite Side – Static Falls

```
MTB > set cl0
DATA> 7.91    7.91    7.95
DATA> 7.61    7.6     7.62
DATA> 8  8  8
DATA> 7.65    7.68    7.67
DATA> 7.75    7.76    7.73
DATA> 7.47.   7.47    7.53
DATA> 7.57    7.51    7.57
DATA> 7.42    7.51    7.48
DATA> 7.39    7.39    7.38
DATA> 7.15    7.13    7.13
DATA> 7.82    7.82    7.79
DATA> 7.6  7.5   7.53
DATA> 7.7  7.69  7.63
DATA> 7.18    7.14    7.13
DATA> 8.02    8.02    8.03
DATA> end

* NOTE   * Text found in data line.

MTB › describe cl0
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
Cl0	45	7.6120	7.6100	7.6154	0.2639	0.0393

Variable	Minimum	Maximum	Q1	Q3
Cl0	7.1300	8.0300	7.4700	7.8050

Board 3 – Ligature Side – Drags

```
MTB > set cl1
DATA> 6.61    6.64    6.59
DATA> 6.61    6.57    6.59
DATA> 6.85    6.84    6.8
DATA> 6.85    6.88    6.8
DATA> 6.78    6.79    6.85
DATA> 6.42    6.38    6.45
DATA> 6.57    6.56    6.55
DATA> 6.53    6.52    6.55
DATA> 6.5  6.51   6.47
DATA> 6.59    6.6     6.6
DATA> 6.43    6.49    6.52
DATA> 6.69    6.61    6.7
DATA> 6.52    6.55    6.58
DATA> 6.63    6.71    6.67
```

```
DATA>  6.68     6.72    6.64
DATA> end
```

* NOTE * Text found in data line.

```
MTB > describe  cl1
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
Cl1	45	6.6220	6.6000	6.6210	0.1284	0.0191

Variable	Minimum	Maximum	Q1	Q3
C11	6.3800	6.8800	6.5250	6.7050

Board 3 – Opposite side – Drags

```
MTB > set cl2
DATA>  7.23     7.23  7.21
DATA> 7.23     7.22  7.22
DATA> 7.25.   7.25   7.17
DATA>  7.2  7.21  7.25
DATA> 7.38   7.37   7.37.
DATA> 6.91   6.94   6.96
DATA>  6.88   6.89   6.82
DATA>  6.95   6.91   6.93
DATA> 6.82   6.74   6.75
DATA>  6.88   6.92   6.94
DATA>  7.26   7.22   7.21
DATA>  7.09   7.12   7.04
DATA>  7.06   7.04   7.04
DATA> 7.29   7.23   7.24
DATA> 7.19   7.18   7.15
DATA> end
```

* NOTE * Text found in data line.

```
MTB > describe cl2
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
Cl2	45	7.0976	7.1700	7.1012	0.1746	0.0260

Variable	Minimum	Maximum	Q1	Q3
Cl2	6.7400	7.3800	6.9350	7.2300

Board 4 – Ligature Side - Static Falls

```
MTB   set cl3
DATA>  9.43     9.41    9.43
DATA>  8.78     8.77    8.79
DATA>  8.24     8.29    8.25
DATA>  9.06     9.04    9.03
DATA>  8.45     8.46    8.39
DATA>  8.19     8.22    8.19
DATA>  8.17     8.17    8.16
DATA>  8.68     8.64    8.66
DATA>  8.78     8.8     8.81
DATA>  10.02    10.01   10.02
DATA>  10.09    10.06   10.05
```

```
DATA> 9.25     9.29    9.23
DATA> 9.36     9.4     9.34
DATA> 9.5  9.48    9.52
DATA> 8.44     8.45    8.39
DATA> end
```

```
* NOTE  * Text found in data line.
```

```
MTB > describe cl3
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
Cl3	45	8.9598	8.8000	8.9441	0.6135	0.0915

Variable	Minimum	Maximum	Q1	Q3
Cl3	8.1600	10.0900	8.4150	9.4200

Board 4 – Opposite Side – Static Falls

```
MTB > set cl4
DATA> 8.81     8.8     8.78
DATA> 8.47     8.5     8.49
DATA> 9.46     9.44  9.44
DATA> 8.54     8.49  8.51
DATA> 9.31     9.35   9.3
DATA> 9.1  9.03    9.06
DATA> 7.51     7.53  7.51
DATA> 7.76     7.75  7.69
DATA> 7.94     7.96  7.91
DATA> 9.04     9  9.03
DATA> 8.45     8.48   8.5
DATA> 7.07     7.09  7.06
DATA> 9    8.98    8.95
DATA> 9.69     9.63   9.7
DATA> 8.47     8.52  8.49
DATA> end
```

```
* NOTE  * Text found in data line.
```

```
MTB > describe cl4
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
Cl4	45	8.569	8.520	8.587	0.724	0.108

Variable	Minimum	Maximum	Ql	Q3
Cl4	7.060	9.700	7.950	9.050

Board 4 – Ligature Side – Drags

```
MTB > set cl5
DATA> 6.43     6.41    6.44
DATA> 6.36     6.4     6.41
DATA> 6.16     6.21    6.17
DATA> 6.37     6.35    6.4
DATA> 6.55     6.56    6.51
DATA> 6.52     6.51    6.51
DATA> 6.55     6.56    6.55
DATA> 6.64     6.61    6.65
```

```
DATA> 6.7  6.73    6.75
DATA> 6.75     6.77    6.75
DATA> 6.47     6.5     6.47
DATA> 6.96     6.98    6.92
DATA> 6.79     6.77    6.78
DATA> 6.9  6.95    6.93
DATA> 6.47     6.51    6.53
DATA> end
```

```
* NOTE   * Text found in data line.
```

```
MTB > describe cl5
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
Cl5	45	6.5824	6.5500	6.5839	0.2097	0.0313

Variable	Minimum	Maximum	Q1	Q3
Cl5	6.1600	6.9800	6.4350	6.7500

Board 4 - Opposite Side – Drags

```
MTB > set cl6
DATA>  6.76     6.78   6.82
DATA>  7.71     7.71  7.74
DATA>  7.22     7.17  7.22
DATA>  8.75     8.72  8.78
DATA>  8.02     7.99  8.03
DATA>  8.47     8.44   8.48
DATA>  7.72     7.69  7.69
DATA>  7.11     7.14  7.12
DATA>  6.6  6.56    6.57
DATA>  6.89     6.92   6.93
DATA>  7.27     7.31  7.3
DATA>  7.71     7.72  7.75
DATA>  7.82     7.87  7.84
DATA> 7.51     7.56  7.55
DATA>  7.38     7.39  7.41
DATA> end
```

```
* NOTE   * Text found in data line.
```

```
MTB > describe cl6
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
Cl6	45	7.5364	7.5500	7.5239	0.5832	0.0869

Variable	Minimum	Maximum	Q1	Q3
Cl6	6.5600	8.7800	7.1300	7.8300

Board 5 – Ligature Side – Static Falls

```
MTB > set
DATA> 10.77    10.76   10.79
DATA> 11.42    11.44   11.45
DATA> 10.03    10.01   10.04
DATA> 10.99    11.01   11.03
DATA>  11  11  10.97
```

```
DATA> 10.1     10.16   10.1
DATA> 9.45     9.43    9.48
DATA> 9.51     9.5     9.45
DATA> 10.79    10.8    10.76
DATA> 10.26    10.24   lb.25
DATA> 9.51     9.53    9.52
DATA> 11.52    11.47   11.53
DATA> 9.69     9.7     9.67
DATA> 10.27    10.29   10.28
DATA> 10.31    10.31   10.29
DATA> end

* NOTE  * Text found in data line.

MTB > describe cl7
```

Descriptive Statistics

```
Variable            N      Mean    Median    TrMean     StDev   SE Mean
Cl7                45    10.375    10.280    10.365     0.670     0.100

Variable      Minimum   Maximum        Q1        Q3
Cl7             9.430    21.530     9.695    10.980
```

Board 5 – Opposite Side – Static Falls

```
MTB > set cl8
DATA> 8.9  8.9     8.86
DATA> 8.65     8.63    8.65
DATA> 8.52     8.61    8.6
DATA> 8.36     8.34    8.33
DATA> 8.9  8.85    8.84
DATA> 8.81     8.77    8.83
DATA> 8.54     8.6     8.55
DATA> 8.43     8.43    8.41
DATA> 9.18     9.14    9.09
DATA> 8.94     8.95    8.93
DATA> 8.44     8.41    8.41
DATA> 8.39     8.38    8.37
DATA> 7.88     7.87    7.83
DATA> 8.28     8.21    8.2
DATA> 8.81     8.85    8.78
DATA> end

* NOTE  * Text found in data line.

MTB > describe cl8
```

Descriptive Statistics

```
Variable            N      Mean    Median    TrMean     StDev   SE Mean
Cl8                45    8.5922    8.6000    8.6007    0.3215    0.0479

Variable      Minimum   Maximum        Q1        Q3
Cl8            7.8300    9.1800    8.3850    8.8500
```

Board 5 – Ligature Side – Drags

```
MTB   set cl9
DATA> 6.98     7  7.01
DATA> 7.48     7.49    7.49
```

```
DATA> 7.72    7.75    7.74
DATA> 6.9  6.94    6.9
DATA> 7.11    7.1     7.08
DATA> 6.95    6.98    7
DATA> 6.85    6.84    6.86
DATA> 7    6.97    6.99
DATA> 6.6  6.59    6.57
DATA> 7.11    7.08    7.09
DATA> 7.29    7.3     7.25
DATA> 7.37    7.39    7.35
DATA> 7.42    7.46    7.45
DATA> 7.23    7.21    7.23
DATA> 7.19    7.15    7.18
DATA> end

*  NOTE  * Text found in data line.

MTB > describe cl9
```

Descriptive: Statistics

```
Variable          N       Mean     Median     TrMean      StDev    SE Mean
c19.             45     7.1476     7.1100     7.1461     0.2821     0.0421

Variable    Minimum    Maximum         Ql         Q3
Cl9          6.5700     7.7500     6.9750     7.3600
```

Board 5 – Opposite side – Drags

```
MTB > set c20
DATA> 6.86    6.9    6.94
DATA> 7.3  7.31    7.22
DATA> 7.14    7.15   7.14
DATA> 7.34    7.29   7.28
DATA> 7.65    7.59   7.59
DATA> 7.37.   7.41   7.37
DATA> 7.37    7.34   7.36
DATA> 7.6  7.58    7.6
DATA> 7.5  7.48    7.41
DATA> 7.42    7.41   7.38
DATA> 7.37    7.36   7.36
DATA> 6.87    6.88   6.86
DATA> 7.08    7.09   7.08
DATA> 7   6.91    6.92
DATA> 7.13    7.18   7.17
DATA> end

*  NOTE  * Text found in data line.

MTB > describe c20
```

Descriptive Statistics

```
Variable          N       Mean     Median     TrMean      StDev    SE Mean
c20              45     7.2569     7.3100     7.2583     0.2304     0.0343

Variable    Minimum    Maximum         Ql         Q3
c20          6.8600     7.6500     7.0850     7.4100
```

Board 6 – Ligature Side – Static Falls

```
MTB > set c21
DATA> 8.87    8.86    8.87
DATA> 9.27    9.31    9.27
DATA> 8.33    8.38    8.36
DATA> 8.79    8.78    8.77
DATA> 9.04    9.02    9.04
DATA> 8.8  8.86  8.85
DATA> 8.32    8.32    8.32
DATA> 8.66    8.65    8.65
DATA> 8.66    8.59    8.63
DATA> 8.61    8.68    8.69
DATA> 8.75    8.74    8.77
DATA> 9.3  9.32  9.31
DATA> 9.01    9.01    8.91
DATA> 9.4  9.41  9.37
DATA> 9.85    9.86    9.81
DATA> end

* NOTE * Text found in data line.

MTB > describe c21
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
c21	45	8.9127	8.8500	8.8956	0.3991	0.0595

Variable	Minimum	Maximum	Q1	Q3
c21	8.3200	9.8600	8.6550	9.2700

Board 6 – Opposite Side – Static Falls

```
MTB > set c22
DATA> 8.54    8.5    8.56
DATA> 8.5  8.48  8.47
DATA> 7.82    7.86    7.82
DATA> 7.64    7.64    7.65
DATA> 8.24    8.26    8.26
DATA> 8.35    8.36    8.33
DATA> 8.18    8.12    8.17
DATA> 8.4  8.48  8.45
DATA> 7.42    7.42    7.42
DATA> 7.92    7.87    7.9
DATA> 8.25    8.27    8.25
DATA> 7.76    7.77    7.78
DATA> 7.72    7.77    7.83
DATA> 8   7.97   7.94
DATA> 8.07    8.77    8.06
DATA> end

* NOTE * Text found in data line.

MTB > describe c22
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
c22	45	8.0720	8.0700	8.0749	0.3430	0.0511

Variable	Minimum	Maximum	Ql	Q3
c22	7.4200	8.7700	7.8000	8.3550

Board 6 – Ligature Side – Drags

```
MTB > set c23
DATA> 7.7 7.72 7.69
DATA> 7.71 7.74 7.76
DATA> 7.8 7.77 7.82
DATA> 7.64 7.64 7.65
DATA> 7.7 7.71 7.69
DATA> 7.31 7.31 7.28
DATA> 7.4 7.42 7.46
DATA> 7.35. 7.37 7.44
DATA> 7.24 7.21 7.27
DATA> 7.45 7.49 7.44
DATA> 7.81 7.82 7.82
DATA> 7.7 7.71 7. 69
DATA> 7.79 7.77 7.77
DATA> 7.81 7.81 7.77
DATA> 7.7 7.69 7.68
DATA> end

* NOTE * Text found in data line.

MTB > describe c23
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
C23	45	7.6116	7.6900	7.6202	0.1906	0.0284

Variable	Minimum	Maximum	Q1	Q3
C23	7.2100	7.8200	7.4400	7.7700

Board 6 – Opposite Side – Drags

```
MTB > set c24
DATA> 7.82 7.81' 7.8
DATA> 7.9 7.9 7.85
DATA> 7.66 7.68 7.63
DATA> 7.61 7.64 7.61
DATA> 7.68 7.77 7.73
DATA> 7.38 7.37 7.39
DATA> 7.46 7.42 7.44
DATA> 7.79 7.85 7.85
DATA> 7.29 7.32 7.31
DATA=- 7.52 7.52 7.51
DATA> 7.52 7.53 7.57
DATA> 7.72 7.72 7.71
DATA> 7.57 7.58 7.59
DATA> 7.69 7.68 7.67
DATA> 7.78 7.79 7.76
DATA> end

* NOTE * Text found in data line.
```

```
MTB > describe c24
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
C24	45	7.6309	7.6600	7.6339	0.1671	0.0249

Variable	Minimum	Maximum	Q1	Q3
C24	7.2900	7.9000	7.5200	7.7750

Board 7 – Ligature Side – Static Falls

```
MTB > set c25
DATA> 9.3  9.29    9.3
DATA> 9.73     9.73    9.69
DATA> 10.11    10.1    10.11
DATA> 9.97     9.95    9.95
DATA> 9.71     9.76    9.74
DATA> 9.57.    9.61    9.56
DATA> 9.91     10  9.95
DATA> 8.9  8.93    8.99
DATA> 8.96     8.93    8.99
DATA> 9.94     9.92    9.96
DATA> 9.27     9.3     9.3
DATA> 10.16    10.15   10.12
DATA> 10.34    10.33   10.32
DATA> 10.23    10.21   10.22
DATA> 9.36     9.33    9.36
DATA> end

* NOTE  * Text found in data line.

MTB > describe c25
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
C25	45	9.7013	9.7400	9.7088	0.4383	0.0653

Variable	Minimum	Maximum	Ql	Q3
C25	8.9000	10.3400	9.3000	10.1050

Board 7 – Opposite Side – Static Falls

```
MTB > set  c26
DATA> 8.75     8.74   8.77
DATA> 8.97     8.99   8.96
DATA> 9.3 9.28   9.3
DATA> 9.48     9.46   9.52
DATA> 9.2 9.21   9.17
DATA> 8.89     8.91   8.91
DATA> 8.23     8.26   8.27
DATA> 8.2 8.16   8.14
DATA> 7.61     7.62   7.65
DATA> 8.25     8.28   8.24
DATA> 8.38     8.41   8.41
DATA> 9.05     9.08   9.06
DATA> 9.51     9.52   9.49
DATA> 8.82     8.83   8.8
DATA> 8.45     8.43   8.45
```

```
DATA> end

* NOTE * Text found in data line.

MTB > describe c26
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
C26	45	8.7424	8.8200	8.7595	0.5284	0.0788

Variable	Minimum	Maximum	Q1	Q3
C26	7.6100	9.5200	8.2750	9.1850

Board 7 - Ligature Side – Drags

```
MTB > set c27
DATA> 7.02   6.98   7.01
DATA> 7.04 . 7.07   7.04
DATA>  7.48.  7.5   7.53
DATA> 7.46   7.45   7.43
DATA> 7.28   7.25   7.24
DATA> 7.69   7.71   7.64
DATA> 7.21   7.25   7.27
DATA> 7.53   7.52   7.51
DATA> 7.93   7.97   7.94
DATA> 7.74   7.78   7.73
DATA> 7.8 7.76   7.83
DATA> 7.68   7.69   7.72
DATA> 7.74   7.76   7.74
DATA> 7.56   7.58   7.56
DATA> 7.12   7.11   7.12
DATA> end

* NOTE * Text found in data line.

MTB > describe c27
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
C27	4 5	7.4882	7.5300	7.4895	0.2877	0.0429

'Variable	Minimum	Maximum	Q1	Q3
C27	6.9800	7.9700	7.2450	7.7350

Board 7 – Opposite Side – Drags

```
MTB > set c28
DATA> 7.77   7.77  7.74
DATA> 7.73   7.73  7.71
DATA> 7.82   7.83  7.79
DATA> 7.62   7.68  7.69
DATA> 7.2 7.23  7.28
DATA> 7.66   7.65  7.6
DATA> 8.03   8.05  8.05
DATA> 8.11   8.08  8.16
DATA> 7.39   7.42  7.44
DATA> 7.5 7.5   7.49
DATA> 7.78   7.74  7.72
DATA> 7.83   7.88  7.85
```

```
DATA> 7.81     7.8     7.78
DATA> 7.92     7.95    7.94
DATA> 7.76     7.73    7.81
DATA> end

* NOTE  * Text found in data line.

MTB > describe c28
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
C28	45	7.7338	7.7600	7.7395	0.2240	0.0334

Variable	Minimum	Maximum	Q1	Q3
C28	7.2000	8.1600	7.6350	7.8400

Board 8 – Ligature Side – Static Falls

```
MTB > set c29
DATA> 9.54'    9.57    9.58
DATA> 8.81     8.8     8.83
DATA> 10.3     10.33   10.34
DATA> 9.61     9.68    9.67
DATA> 10.22    10.21   10.23
DATA> 9.41     9.44    9.42
DATA> 10.11    10.1    10.17
DATA> 8.91     8.9     8.91
DATA> end

* NOTE  * Text found in data line.

MTB > describe c29
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
c29	24	9.629	9.595	9.634	0.550	0.112

Variable	Minimum	Maximum	Q1	Q3
c29	8.800	10.340	9.035	10.200

Board 8 - Opposite Side – Static Falls

```
MTB > set c30
DATA> 9.3 9.32   9.27
DATA> 8.56     8.57    8.57
DATA> 8.17     8.16    8.11
DATA> 9.31     9.32    9.36
DATA> 9.77     9.72    9.73
DATA> 8.96     9.02    8.97
DATA> 10.02    10.06   10
DATA> 8.9 8.93   8.91
DATA> end

* NOTE  * Text found in data line.

MTB > describe c30
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
c30	24	9.125	9.145	9.129"	0.582	0.119

Variable	Minimum	Maximum	Q1	Q3
c30	8.110	10.060	8.653	9.630

Board 8 – Ligature Side – Drags

```
MTB > set c31
DATA> 6.9   6.92   6.9
DATA>  7    7  7.01
DATA>  6.81     6.82    6.85
DATA>  7.06     7.02    7.06
DATA>  7.31     7.33    7.36
DATA>  7.29     7.33    7.29
DATA>  7.16     7.12    7.12
DATA>  7.17     7.13    7.2
DATA>  end.

* NOTE   * Text found in data line.

MTB > describe c31
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
c31	24	7.0900	7.0900	7.0905	0.1723	0.0352

Variable	Minimum	Maximum	Q1	Q3
c31	6.8100	7.3600	6.9400	7.2675

Board 8 – Opposite Side – Drags

```
MTB > set c32
DATA> 6.32     6.32    6.33
DATA> 7.6  7.64    7.58
DATA> 7.37     7.43    7.38
DATA> 7.81     7.85    7.86
DATA> 7.78     7.76    7.72
DATA> 7.47     7.44    7.43
DATA> 7.38     7.32    7.35
DATA> 7.4  7.44    7.44
DATA> end

* NOTE   * Text found in data line.

MTB >  describe c32
```

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
C32	24	7.3925	7.4400	7.4200	0.4466	-0.0912

Variable	Minimum	Maximum		Q3
C32	6.3200	7.8600	7.3725	7.7000

APPENDIX H – REFERENCES CITED

REFERENCES CITED

Boltz, W. (1956) Mord durch Erhängen oder fahrlässige Tötung? *Archiv Für Kriminologie.* Vol 117: 133-139.

Budworth, G. (1985) Knots and Crime. Police Review Publishing Company: London.

Cooke, Clive T., Cadden, Gerard A, and Hilton, John M.N. (1988) Unusual Hanging Deaths. *The American Journal of Forensic Medicine and Pathology. 9(4): 277-282.*

Davison, A., and Marshall, T. K. (1986) Hanging in Northern Ireland – A Survey. *Medicine, Science, and the Law. 26(* 1): 23-28.

Fisher, B. A. J. (1993) Techniques of Crime Scene Investigation. Fifth edition. CRC Press Inc: Florida.

Goddefroy, E. V. (1923) Selbstmord durch Erhängen oder Mord mit nachfolgender Aufhängung der Leiche, urn Selbstmord vorzutäuschen? *Archiv Für Kriminologie.* Vo175: 226-227.

Health Canada (1994) Suicide in Canada: Update of the Report of the Task Force on Suicide in Canada. Sponsored by the Mental Health Division. Health Services Directorate. Health Programs and Services Branch, Health Canada. http://www.hc-sc.gc.ca/hppb/mentalhealth/pdfs/suicide.pdf

Hucker, S. J., and R. Blanchard. (1992) Death Scene Characteristics in 118 Fatal Cases Of Autoerotic Asphyxia compared with Suicidal Asphyxia. *Behavioural Sciences and the Law.* Vol 10: 509-523.

Jaffe, F. A. (1999) A Guide to Pathological Evidence: For Lawvers and Police Officers. Fourth Edition. Thomson Canada Limited. Ontario, Canada.

Kipper, F. (1926) Mord durch Erhängen. *Archiv Fiir Kriminologie.* Vo178: 213-228.

Klauer, H. (1933) Untersuchung von Strangwerkzeug und Aufhängeort beim fraglichen Erhängungstod. *Dtsch. Z Gerichtl. Med.* Vol 20: 375-385.

Leth, P., and A. Vesterby. (1997) Homicidal hanging masquerading as suicide. *Forensic Science International. 85: 65-71.*

Lew, E.O. (1988) Homicidal Hanging in a Dyadic Death. *The American Journal of Forensic Medicine and Pathology. 9(4): 283-286.*

Mueller, B. (1932) Ein Beitrag zur kriminalistischen Bedeutung der Berufsknoten. *Archiv Für Kriminologie.* Vol 9 1: 175- 18 1.

Nicholls, T. (2000) Hangings – A Practical Study of Ligatures and Suspension Point Morphology. (B.Sc. thesis, unpublished), University of Toronto at Mississauga.

Popp, G. (193 1) Mord oder Selbstmord bei aufgehängten Leichen. *Archiv Für Kriminologie.* Vo188: 78-81.

Ptischel, K., Holtz., W., Hildebrande, E., Naeves, W., and Brinkmann B. (1984) Hanging: Suicide or Criminal Offence? *Criminology Archives.* 174(6): 141-153.

Radian I. And Radovici, L. (1957) Sur un cas d'homicide par pendaison. *Annales de Médicine Légale et de Criminologie.* Seance du 8 Juillet 1957, p. 232-236.

Rooks, G. (1935) Selbstmord durch Erhängen oder mord mit darauffolgendem Aufhängen der leiche? *Archiv Für Kriminologie* Vo197: 104-l 10.

Shearer, Don (2000) Personal communication regarding coroner's inquest into a suspicious hanging death

Simon, R. (1998) Murder Masquerading as Suicide: Postmortem Assessment of Suicide Risk Factors at the Time of Death. *Journal of Forensic Sciences. 43(6):* 1119-l 123.

Spitz, W. U., and Fisher, R. S. (1980) Medicolegal Investigation of Death: Guidelines for the Application of Patholoav to Crime Investigation. Second Edition. Charles C. Thomas: Illinois.

Vieira, D.M., Pinto, A.E., and Oliveira Sá, F. (1988) Homicidal Hanging. *The American Journal of Forensic Medicine and Pathology. 9(4): 287-289.*

Webster, P. (2001) Unpublished B.Sc. Thesis, Forensic Science Mentorship, Hanging Study. University of Toronto at Mississauga.

Weimann, W. (1929) Mord an der Ehefrau und Vortäuschung eines Selbstmordes durch nachträgliches Erhängen. *Archiv Fiir Kriminologie.* Vo184: 135-144.