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Oxygen Saturation among Newborn Infants and the Decrease Occurring During Feeding in Various Populations

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OXYGEN SATURATION AMONG NEWBORN INFANTS AND THE DECREASE OCCURRING DURING FEEDING IN VARIOUS POPULATIONS

BY

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Abstract

Pharyngeal and laryngeal structural movements coordinate respiration and swallowing functions, hence eliminating simultaneous execution. This research aims to document levels of oxygen saturation during rest and feeding among various newborn populations. Hypothesized is that an increase in oxygen alterations during feeding will be exhibited by infants of younger gestational age and, further, by those with the presence of respiratory anomalies.

Thirty newborns in the nurseries at Medical University of South Carolina, free of cardiac and genetic maladies, were divided into three groups. Subjects of group 1 are healthy, full-term newborns; within groups 2 and 3, preterm infants (<37 weeks gestation). Subjects of groups 1 and 2 have no diagnosed respiratory disorders; those within group 3 have diagnoses of respiratory illness.

Nellcor pulse-oximeters monitor infants during sleep and feeding sessions. ANOVA data analysis revealed no statistical difference within this sample. A pattern of increased changes suggests clinical significance. Future studies may find it beneficial to use a larger sample size powered to detect a smaller effect size.

CHAPTER I
INTRODUCTION

Background and Need

Infants are successfully brought into this world at earlier and earlier ages as technology and health care improves. As these newborns are increasingly immature in their development at the time of delivery, each individual requires a greater amount of care and attention. A great deal of research has been conducted regarding the overlap in mechanical functioning of the respiratory and feeding apparatuses. However, there are only a limited number of studies that incorporate these functional activities to the life and development of infants.

Respiratory and feeding issues correlate as the structures of the pharynx perform both functions. Therefore, it is impossible for a person, regardless of age, to breathe and swallow simultaneously. Due to the relationship of feeding and breathing, it is understood that respiratory rate decreases during feeding sessions. In turn, it can be expected that the level of one's oxygen saturation (SaO_2) in the blood may be altered by the feeding sessions.

Researchers have documented a change in these SaO_2 levels during various activities. However, there has been little attention to the prevalence of these factors in the newborn population. Individual factors including an infant's health status and age create a wide continuum along which these infants are ranked.

Infants are targeted for this study to determine the effects of changes in SaO_2 during feeding as infants develop the coordination of the suck-swallow-breathe sequence. It has been documented that this desaturation occurs in adults. It is now important to explore a potentially similar phenomenon within the pediatric population and determine an average level of saturation changes and recovery time after feeding as well as the variation that occurs within diverse groups of infants.

Problem Statement

This research focuses on the SaO_2 levels infants present based upon their classification of age and respiratory status. Pre- and full- term infants are studied. In addition, a variable of respiratory disorders is added within the preterm infant sample. Therefore, the healthy, normal full-term infants serve as the control group.

Research Questions

Questions addressed through this research are as follow:

1) What is an average degree of SaO_2 change during feeding compared to that during rest in the population of full-term infants?
2) What is an average degree of SaO_2 change during feeding compared to that during rest in the population of preterm infants with respiratory anomalies?
3) What is an average degree of SaO_2 change during feeding compared to that during rest in the population of preterm infants without respiratory anomalies?
4) How do the changes in SaO_2 during feeding compare among full-term infants and those who are preterm with and without respiratory anomalies?

5) To what degree are full-term infants able to recover from altered SaO_2 during feeding compared to preterm infants with respiratory disorders and those without respiratory disorders?

Population

The subjects participating in this study include three groups of newborn infants, each with specific inclusion and exclusion criteria. Infants are targeted within this study in order to establish comparative data regarding gestational age and respiratory status as they relate to SaO_2 and feeding. All infants participating in this study are patients at the Medical University of South Carolina Hospital and are free of any genetic, cardiac, or neurologic0 disorder. The control group will involve a sample of healthy, normal full-term infants under the care in the normal newborn nursery. The sample group of preterm, normally developing infants may be cared for in either the Level 1 (normal newborn nursery) or the Level 2 nursery. The third group of subjects includes preterm infants with respiratory conditions will be patients cared for in the Medical University of South Carolina Neonatal Intensive Care Unit (NNICU) or Level 2 nursery.

Operational Definitions

Throughout this research, the following will terms will be used according to the definition and criteria outlined below:

1) *Active sleep*: visible rapid eye movements are noted beneath the closed eyelid and irregular breathing rates and physical body movements are observed
2) *Quiet sleep*: the infant is still, with eyes closed; no eye movements are noted; breathing rates are stable and regular
3) *Aspiration:* passage of fluid through the vocal folds toward the lungs

4) *Corrected age:* continued age measurements from conception; weeks are accumulated even after the baby is delivered (i.e. a baby born at 23 weeks gestation and has lived postnatally 4 weeks has a corrected age of 27 weeks)
5) *Feeding readings*: will be recorded throughout the feeding session as the bottle is presented by the parent, caregiver, or nurse as is usual for the individual; recordings will begin as the bottle is presented and continue until the bottle is removed and the infant has finished eating; pauses in the feeding (for burping or fussiness) will be noted and readings will not be noted during these pauses
6) *Nipple feeding*: use of a uniform Similac (Ross Products) standard nipple in the normal newborn nursery and the NNICU
7) *Nonnutritive sucking:* activity of sucking is demonstrated without nutritive fluid being extracted from the source (i.e. thumb or pacifier)
8) *Preterm infants*: infants born less than or equal to 37 weeks gestational age
9) *Pulse oximeter*: Nellcor pulse oximeter sensors will be used on each subject; Hewlett Packard monitors will display the SaO_2 readings
10) *Abbreviations*:
    - SaO_2: oxygen saturation
    - CLD: chronic lung disease
    - RDS: respiratory distress syndrome
    - RSV: respiratory syncytial virus
    - BPD: bronchopulmonary dysplasia
    - NNICU: neonatal intensive care unit

Assumptions

It is assumed that the infants both in the NNICU and the normal newborn nursery participating in this study are representative of all infants within these specified criterion groups. The assumptions incorporate the understanding that these children require special attention and care associated with their fragile state.

All children will have a range of behaviors during the day; therefore, it is assumed through this study that the behavioral variations among children will be appropriately distributed among each group of infants and will affect each comparably. This research is designed to be non-invasive but to determine valuable information regarding this population.

CHAPTER II
LITERATURE REVIEW

Introduction

Literature reviewed within this chapter will deliver information regarding the issue of prematurity within the newborn population, an overview of the anatomy responsible for breathing and feeding, and the development of each function. In addition, a variety of factors influencing the respiratory system and the feeding abilities will be emphasized. Research will also be presented about several lung disorders exhibited by many infants. With knowledge of the respiratory diseases, one is able to determine any relationship these may have on the development of feeding.

Literature searches were performed focusing on the specifics of each of the above topics. The result is a list of journal articles, reference chapters, and books that appropriately document various aspects of development, feeding, respiration, and SaO_2 associated with the newborn population. Research studies and documents used in reviewing this material span from early documentation in 1972 to recent studies of 2001. Though there have been several publications through the years, the majority of the materials presented in this review were compiled since 1993.

Prematurity

Determining prenatal development and a degree of prematurity has created controversy through the years. There have been differing theories pertaining to the criteria one must meet to be deemed "preterm." Prematurity was first addressed in 1886

and described on the basis of birth weight. This theory did not prevail due to the later discovery that infants born full-term may also weigh less than the average amount. Therefore, it was determined that criteria for prematurity must be determined by postnatally assessing a child's gestational age (Sola, A. & Chow, L. C., 1999).

The movement toward gestational age determinations led professionals in search of an appropriate measure of development *in utero* that would be applicable as a postnatal evaluation tool. Sola and Chow (1999) report on the needs for physical assessment as well as a neurological assessment to take into account all aspects of the infant's musculature and reflexes. These researchers report that the theory of muscle tone influencing the embryological development was abandoned due to extraneous conditions that affect this aspect. In 1970, Dubowitz, Dubowitz, and Goldberg (in Sola & Chow, 1999) developed a scale on which newborns would be rated to determine gestational age. The assessment criteria is based on ten physical characteristics and eleven neurological criteria. The process of completing this assessment proved to be tedious and complex (Sola & Chow, 1999). Therefore, the New Ballard Score was developed in an attempt to create a more concise yet accurate and reliable developmental rating scale (Bernbaum & Batshaw, 1997). Ballard succeeded in authoring a more succinct measure known as the New Ballard Scale as the criteria include six physical and six neurological criteria (Appendix B). However, there is some ambiguity regarding the reliability of this tool. Sola and Chow (1999) express concern that this test is adequate for infants of 34-40 weeks gestation, but there is an increased need in determining gestational age between 22 and 28 weeks due to the decreased reliability presented regarding infants less than 28 weeks gestation. Ballard, Koury, Wedig, Wang, Eilers-Walsman, & Lipp (1991) concur

with the preceding statements as they describe the assessment as having the highest level of accuracy and reliability between 32 and 37 weeks gestation. In evaluating the various procedures for determining an infant's gestational age, Sola and Chow (1999) state that an optimal estimate of gestational age would be based on the date of the last menstrual cycle, a physical exam, and the findings during a first trimester ultrasound.

It appears several researchers have dedicated large amounts of time to resolving the issue of gestational age. This is an important issue because an accurate gestational age recording may offer information regarding the patient's development in the womb and shed insight to any pathologies that may affect the child (Sola & Chow, 1999).

As gestational age is determined, a preterm newborn is defined as any infant born less than 37 weeks gestation (Dirckx, 1997). Many factors may contribute to an infant being delivered preterm. These include, but are not limited to, poor nutrition, poor prenatal care, drug use, toxemia, multiple birth occurrences, weak cervical muscles, previous births, and adolescent mothers due to an immature uterus (Bernbaum & Batshaw, 1997). Babies qualifying for this category are extremely fragile and are immediately considered being at an increased risk of developing a range of conditions. These include jaundice, hypoglycemia, hypocalcemia, hypothermia, and a variety of respiratory disorders (Bernbaum & Batshaw, 1997).

Other primary system disorders are of interest to monitor among children who were born preterm. Respiratory abnormalities exhibited in early childhood are strongly correlated with small infants born at decreased gestational ages (Shennan, Dunn, Ohlsonn, Lennox, & Hoskins, 1988). Gestational age alone does not correlate with motor or mental developmental impairments. However, a 1999 study by Cheung, Barrington,

Finer, & Robertson presented a correlation in these factors when an additional condition of intraventricular hemorrhage was involved.

Though birth weight is no longer used for establishing prematurity, it is used to classify infants who may not have developed weight normally in the womb. Newborns are categorized into levels of low birth weight depending upon that measured at birth, regardless of the term of the pregnancy and status of prematurity. Infants who are born weighing 1500-2500grams are considered to be *low birth weight (LBW)*; those with birth weight equaling 1000-1500g are labeled as *very low birth weight (VLBW)*. Further, infants weighing 800-1000g are *extremely low birth weight (ELBW)*, and those weighing less than 800g are considered *micropremies* (Bernbaum & Batshaw, 1997).

Bernbaum and Batshaw (1997) have emphasized the improvement in technology and infant care through the years and provided statistics regarding low birth weight survival rates in 1960 and 1990. Only ten percent of all infants with birth weight less than 1000g survived in 1960; by 1990, this percentage was increased to a survival rate of 66-75% of all infants weighing 750-1000g and 33% for infants of 500-750g. Less than 30% of all VLBW infants survived in 1960 while over 90% persevered in 1990. In comparison, survival rates for preterm infants improve as gestational age increases. Sola and Chow claim survival rates in 1999 to be 43%, 74%, and 83% at 24, 25, and 26 weeks gestational age, respectively. Reviewing the statistics of infant survival rates based upon gestational age and birth weight, it is clear that science's understanding of the newborn human has increased and available care has improved through the years.

Anatomy

Human anatomy is a complex intertwining of functions and the structures that develop to create precise, sequential execution of these operations. In the third trimester of pregnancy, the infant develops increased muscle tone and changes in reflex activity. Therefore, since preterm infants do not remain *in utero* the entire third trimester, these infants will be born with decreased muscle tone and abnormal reflexes. Specifically, infants born at less than 28 weeks gestation present with floppy muscle tone that will increase in the lower extremities initially and then progress to improved tone in the upper extremities. Comparatively, a full-term infant demonstrates a semi-flexed resting position at birth (Bernbaum & Batshaw, 1997).

Physical characteristic differences between pre- and full-term infants are noted in respect to the level of gestational development the newborn has completed. Decreased skin creases in the foot are present until 32 weeks gestation. Infants less than 34 weeks will not have developed breast buds or ear cartilage. A layer of fine hair, called *lanugo*, covers the entire body in preterm infants and is customarily lost at 38 weeks gestation. In addition, infants' skin has not fully developed and may appear translucent or red in color due to the shallow vascular system in the preterm infant. These characteristics will develop, as the infant ages to a 40-week gestational age, equal to that of a full-term infant (Bernbaum & Batshaw, 1997).

Anatomical structures may be responsible for several life-sustaining functions. Respiration, swallowing, and phonation are all achieved by adequate functioning of the pharynx and larynx (Loughlin & Lefton-Greif, 1994). As respiration and swallowing territories overlap in the body, it is important to understand the differences in the path of

each. Of these activities, the sole action of swallowing requires the coordination of five cranial nerves and over twenty muscle pairs (Comrie & Helm, 1997).

The infant presents with a tongue that is quite large in relation to the size of the oral cavity as it fills most of the space. The tongue size aids the infant in containing the bolus in the mouth to prepare for a swallow (Comrie & Helm, 1997). An infant's buccal pads are used to further contain the bolus and prepare for feeding. During a swallow, the airway must be protected to eliminate aspiration. This is achieved by closure of the vocal folds, a cessation of respiration, and a cough reflex in the instance that the fluid passes into the larynx. A newborn's small size warrants little structures that are obviously set closer together in comparison to subjects who are more maturely developed. The close proximity of structures enables the infant to channel food down the esophagus and, thus, experience a low occurrence of breathing interruptions of the swallow (Loughlin & Lefton-Greif, 1994). Appendix A includes a graphic representation of the infant's pharyngeal anatomy in comparison to that of a mature adult.

Respiration involves the passage of air through the pharynx and larynx and into the lungs. Surfactant is a chemical found in the lung that performs an imperative function involving the alveolar sacs. The alveolar surface is covered by surfactant in order to decrease the surface tension. Decreased surface tension protects the air sac against excessive inflation or deflation, either of which could be detrimental to the lung (Ballard, 1988).

Each anatomical structure involved in the feeding or respiratory system is integral to the performance of coordinated sequences and the achievement of life-sustaining

functions and serve as precursors to the development of speech and social activities (Walter, 1998).

The Feeding Process

Proper development of feeding patterns incorporates the movements of the oral cavity, pharynx, larynx, and esophagus. An infant progresses through the feeding stages of suckling, sucking, and chewing as she grows and matures. Initially, the motion of the tongue within the oral cavity must develop (Glass & Wolf, 1994). Comrie and Helm (1997) describe the intraoral tongue shape of suckling as having the lateral edges of tongue elevated while the medial tongue dips to produce a passageway for milk. The milk then travels until the medial tongue pushing the milk back to the pharynx initiates the swallow. Suckling persists for approximately the first six months before the infant's feeding pattern matures to a suck.

Bu'Lock, Woolridge, and Baum (1990) emphasize the pattern of an infant's suck as an integral coordination of muscle contractions and repetitive wavelike tongue movements. Thus, the bolus is moved through the mouth in an antero-posterior motion toward the pharynx as the tongue base retracts and the epiglottis folds to cover the airway opening of the larynx. Further, the soft palate elevates as the bolus approaches the pharynx in order to prevent any nasal regurgitation of the bolus. The esophagus contracts reflexively and applies continued force to the bolus, thus causing the bolus to move toward the stomach (Bu'Lock, Woolridge, & Baum, 1990).

The act of swallowing has been reported to occur *in utero* beginning between 11 and 16 weeks gestation (Comrie & Helm, 1997; Loughlin & Lefton-Greif, 1994; Bu'Lock, Woolridge, & Baum, 1990). Comrie and Helm (1997) report that the volume

of amniotic fluid ingested in utero increases with development and gestational age. Though the act of swallowing is documented to develop early in embryological development, it is found that the coordination of sucking and swallowing does not evolve until approximately 32 weeks gestation (Hill, 1992; Bernbaum & Batshaw, 1997). Therefore, infants born at less than this age are fed via nasogastric (NG) tube until this coordination has adequately developed (Bernbaum & Batshaw, 1997). When development is adequate, infants demonstrate two phases of *continuous* and *intermittent* sucking patterns during a feeding session (Hill, 1992; Mathew, 1991; Koenig, Davies, & Thach, 1990). The continuous suck dominates the first two minutes of the feeding and is characterized by an uninterrupted sucking pattern. The subsequent phase of intermittent sucking presents 3-5-second pauses during sucking throughout the feeding session (Koenig, Davies, & Thach, 1990).

Influences of Feeding

Gestational Age

Decreased musculoskeletal support exhibited in preterm infants creates an inadequate postural foundation for appropriate feeding techniques (Comrie & Helm, 1997). Infants mature physically and neurologically as gestational age increases. This development is required to produce independence and self-sufficiency. Gestational age is, thus, a more reliable relationship to infants' feeding demonstration than is the infant's postnatal age (Kennedy & Lipsitt, 1993; Bu'Lock, Woolridge, & Baum, 1990). However, any anomaly of the respiratory, cardiac, craniofacial, or neurological system can increase the complications associated with feeding (Comrie & Helm, 1997).

Transition to Oral Feeding

Provided an infant's gestational age and health status, NG tube feedings may be implemented prior to the initiation of oral feeds. When the infant has demonstrated medical stability, then a referral for oral feeds may be completed. Transition from the NG tube to an oral tube may cause cyclical disadvantages for the child. This occurs as the infant receives decreased nutrition caused by poor coordination of sucking, swallowing, and breathing. Respiratory disorders increase this risk and may substantiate the replacement of the NG tube. In turn, the replacement creates increased respiratory difficulty as one nostril is obstructed by the feeding tube (Bazyk, 1990).

Transition to oral feedings may also be delayed based upon the gestational age of the child. The younger the child is developmentally, the longer one can expect for her to develop the advanced coordination of the suck-swallow-breathe pattern necessary for successful in oral feeding (Bazyk, 1990). Infants must be cared for and monitored closely during feeding sessions. Comrie & Helm (1997) outline warning signs of stress during feeding to be expressed by several physical characteristics. These include audible breathing, nasal flaring, respiratory stridor, gasping, coughing, and respiratory compromise.

Feeding Coordination

Even though swallowing has been reported early in embryological development, sucking, swallowing, and breathing are not fully developed and coordinated until 32 to 34 weeks gestation (Hill, 1992). Therefore, general procedures suggest 34 weeks gestation to be an appropriate time to initially present nipple-feedings for preterm infants (Comrie & Helm, 1997; Glass & Wolf, 1994; Kennedy & Lipsitt, 1993). With a more

conservative view, Loughlin and Lefton-Greif (1994) declare that these functions are not yet fully coordinated until between 34 and 36 weeks gestation even though the swallow is more efficient. These authors state that infants experience apnea (breathing cessation) during feedings more often when feedings are presented before the neonate is 37 weeks gestational age.

In addition, Glass and Wolf (1994) report apneic episodes occurring at an increased rate at the beginning of feeding sessions due to the rapid suck-swallow rate infants employ. This coincides with the phase of continuous sucking described by Koenig, Davies, & Thach (1990). In general, an increase in gestational age improves the consistency of a feeding pattern. When this ability has evolved, the newborn will present with suck: swallow: breathe ratio of 1:1:1. In the case of infants with low gestational ages, an increase in the alternating "breathing bursts" and apneic episodes persists with stages of zealous feedings (Bu'Lock, Woolridge, & Baum, 1990). Feeding requires a great deal of coordination and energy on the part of the infant. Thus, preterm infants easily fatigue when bottle-feeding is introduced (Comrie & Helm, 1997).

Feeding difficulties may often be the only problem infants present. The swallow interrupting the breath in the 1:1:1 sequence characterizes uncoordinated sequencing of the feeding pattern. Preterm infants often have difficulties developing appropriate feeding patterns due to the high level of coordination required between sucking and swallowing. In addition, the integration of respiratory control during feeding causes difficulty for the fragile newborn (Bu'Lock, Woolridge, & Baum, 1990). It must also be considered that full-term infants may present challenges with feeding. Healthy, full-term neonates also present with feeding patterns that are not completely coordinated. Thus, this appears to

be developmental and not necessarily an abnormal behavior (Koenig, Davies, & Thach, 1990). Bu'Lock, Woolridge, & Baum (1990) report that term infants may need three to four days to develop a feeding pattern that is considered "normal." The sudden change in environment and presentation of food requires a high level of adaptation on the part of the child, and, with time, most children will develop the coordination to orally feed.

Breast vs. Bottle

It is recommended that oral feeds incorporate breast milk whenever possible due to reports that the natural enzymes in breast milk increase the protection against infection. Specifically, formula presented early in feeding development has led to increased cases of infants acquiring necrotizing entercolitis (NEC). The protection may be achieved by increased use of feedings that present breast milk alone or with supplemental nutrients (Bernbaum & Batshaw, 1997). Studies also indicate that oral feeds presented by breast may be more appropriate at an early age than are those presented by bottle (Comrie & Helm, 1997; Glass & Wolf, 1994). Glass and Wolf (1994) state infants' coordination of the S: S: B pattern is intact at 32 weeks and adequate to proceed with breast-feeding.

There are several aspects of bottle-feeding to consider when presenting a neonate with a bottled oral-feed. Nipples vary in size for the infant's mouth and in the size of the hole for milk-flow. The rate of the milk-flow is known to alter the breathing pattern demonstrated by infants (Comrie & Helm, 1997). The size of the feeding hole may affect the amount of fluid to the mouth and, thus, compromise the infant's ability to coordinate her breathing as the milk-flows at a rate faster then she can manage (Mathew, 1991). Glass and Wolf (1994) describe the relationship between the flow rate of milk as being indirectly proportional to the S: S: B rate. Therefore, a high rate of milk-flow constitutes

a decreased feeding rate because of the large volume of fluid exiting the nipple from a single suck. In contrast, a nipple with low milk-flow rates requires more effort and sucks to retrieve an appropriate volume. A report from Mathew in 1991 agrees with the prior findings as he reports a higher incidence of minute ventilation and breath frequency decreases when the infant feeds with high-flow rate nipples.

Overlap of Respiration and Feeding

Both the processes of respiration and swallowing employ the anatomical structures of the pharynx and larynx. As illustrated by the mechanics of a swallow, it is impossible for a human to naturally breathe and swallow simultaneously (Comrie & Helm, 1997; Mathew, 1991; Koenig, Davies, & Thach, 1990). However, Comrie and Helm (1997) declare that it is possible for the infant to breathe as she sucks. This is made possible by the velo-epiglottic engagement located where the epiglottis meets the soft palate, thus protecting against any flow of liquid into the pharynx prior to the initiation of the swallow. Loughlin & Lefton-Greif (1994) emphasize the importance of the structures' appropriate function and mechanical sequencing in order to "prevent the contamination of the respiratory system during swallowing" (p. 138).

The onset of a swallow is often preceded by a short breath (Loughlin & Lefton-Greif, 1994) in preparation for the decreased respiration that will occur during the swallow (Koenig, Davies, & Thach, 1990) as the larynx elevates and is protectively covered by the epiglottis. Upon completion of the swallow, it is beneficial to exhale. Inspiration occurring at this time constitutes an increased risk of aspirating as any residue from the pharynx is inhaled (McPherson, Kenny, Koheil, Bablich, Sochaniwskyj, & Milner, 1992).

Significant overlap in the functions, structures, and sequencing of these systems composes a conceivable need to monitor the activity of each system. Breathing is a necessity, yet it is slowed by the swallowing process. Inappropriate execution of a breath during a swallow may alter the direction of fluid from the posterior esophageal opening to the parallel anterior airway. Similarly, muscular weakness may cause an infant to have decreased control over the fluid, allowing the fluid to flow into the airway rather than be appropriately directed to the esophagus.

Pulse oximetry

Advantages and Disadvantages

Pulse oximeters are noninvasive machines commonly used to monitor SaO_2 of the subject's blood and establish baseline readings, any changes affected by work, and any alterations resulting from oxygen therapy (Arvedson & Lefton-Greif, 1998). Attachment of the pulse oximeter probe should be done with care and appropriate attention. The probe is most often attached to the finger or foot (McConnell, 1999; Levesque, Pollack, Griffin, and Nielson, 2000). In preparing the site for probe application, it is important to clean the site, check the circulation, and rule out any signs of vascular dysfunction in the area. Monitoring the patient is necessary to maximize her comfort and guard against decreasing the circulation in the area (Gallauresi, 1998). If the vascular systems are not adequate in the finger or foot, a probe may be attached to the earlobe or bridge of the nose (McConnell, 1999).

A routine monitoring device used in the Neonatal Intensive Care Unit, the pulse oximeter is a reliable, noninvasive machine. However, there are some disadvantages and possible damaging side effects that may result from the use of pulse oximeters (Botet,

Rodriguez-Miguelez, Figueras, 1999). Some of these drawbacks include the following: 1) sensitivity to movement may create a false alarm regarding a low SaO_2 reading that is only caused by a kick or flailing arm; 2) recordings of SaO_2 levels are completed by measuring infrared light absorption; this causes recordings of increased estimates in dark-pigmented skin; 3) external light may affect the readings (Arvedson & Lefton-Greif, 1998); and 4) a weak pulse may cause the SaO_2 readings to be low (Underhill, 1999). In addition, there have been studies regarding a few cases in which subjects experienced tissue necrosis at the site of the pulse oximeter. The risk of this occurrence is elevated for patients with decreased vascular circulation or thin skin (Botet, Rodriguez-Miguelez, & Figueras, 1999). Goodman and Johnson (1999) warn about the oximeter due to the placement of a heat sensor within the oximeter that may overheat and cause burns. Those responsible for monitoring the patient should watch for circulation adequacy to prevent any major subsequent damages. Changing the probe's position could help to decrease the pressure and heat applied to the site monitored (Underhill, 1999).

Normal Oxygen Saturation

The establishment of normative data in relation to SaO_2 levels in the infant population is important in order to gage a sense of normality among individuals (Levesque, Pollack, Griffin, and Nielson, 2000). Normal levels of SaO_2 as measured by pulse oximetry range between 95-100% (Arvedson & Lefton-Greif, 1998). These SaO_2 readings are considered accurate and reliable because they closely correlate with those measured by arterial blood gas laboratories provided that the subject does not have a peripheral vascular disorder and the SaO_2 is maintained greater than 70% (McConnell,

1999). Recordings below 90% are considered indicative of some degree of hypoxia (Arvedson & Lefton-Greif, 1998).

In 1992, Hill emphasized the need to monitor the infants' SaO_2 levels in order to guard against trauma or stress and fully benefit the children according to their individual physiological needs. In agreement, Cheung et al. (1999) articulated the need to document and guard against apnea defined as an SaO_2 decrease greater than ten percent. These researchers state, "apnea with marked desaturation and a high frequency of apnea can lead to decreases in oxygen delivery to the brain, which in turn may modify subsequent neurodevelopment" (p.19). Significant oxygen desaturation may also cause the development of cyanosis and bradycardia (Hill, 1992).

Oxygenation and Feeding

Pulse oximetry is used during feeding sessions to monitor for hypoxia (Loughlin & Lefton-Greif, 1994) due to the knowledge that decreases in SaO_2 may be caused by feeding-induced apnea (Comrie & Helm, 1997). Therefore, pulse oximeters are useful supplemental guides for evaluating one's respiratory status prior to the development of physical stress indicators (Arvedson & Lefton-Greif, 1998).

Decreases in SaO_2 during feeding are representative consequences of respiratory cessation during the swallowing portion of feeding (Comrie & Helm, 1997). From a study of newborns, Hill (1992) reports SaO_2 data revealing decreases from a mean baseline recording of 96.67% to a range of 90.65-95.28% during feeding. There is much controversy regarding an appropriate level of SaO_2 decrease, and no normative data is available on the subject. However, the presence of these decreases is considered in relation to the population at hand. Glass and Wolf (1994) believe that an SaO_2 decrease

during feeding in full-term infants is not significant. On the other hand, these researchers do express concern for those infants who are less medically stable as the SaO_2 decrease may have increased significance in these cases. Hill (1992) supports this notion as she determined that decreases in SaO_2 were not significant enough to denote a change in clinical practices given the data revealing that infants are able to recover effectively. The more mature infants implemented patterns of the intermittent suck phase to achieve this recovery; the less mature infants are unable to perform this transition.

The issue surrounding questions about breast- and bottle-feeding spans to the point of SaO_2 levels. Dowling reported in 1996 that breast-feeding infants exhibit less desaturation than do those who bottle-feed. He also stated that the sucking patterns varied depending upon the food source in these infants. This is contradicted by a study by Bu'Lock, Woolridge, and Baum (1990) reporting that no differences were noted in the sucking patterns of those breast-fed compared to those who are bottle-fed. However, a third report, by Chen, Wang, Chang, and Chi (2000), compares infants' SaO_2 levels during feeding from the breast and from the bottle. The breast-fed infants demonstrated neither apneic periods nor any SaO_2 levels less than 90%. In comparison, the bottle-fed infants exhibited two periods of apnea and 20 recordings less than 90% SaO_2. Comrie and Helm (1997) support this notion that SaO_2 decreases at a greater rate during bottle-feeding than during breast-feeding.

Levesque et al. (2000) assessed SaO_2 in relation to several independent variables including gender, APGAR, gestational age at birth, birth weight, mode of delivery, activity state, and location of the sensor. Findings revealed that SaO_2 levels are not influenced by gender, gestational age at birth, birth weight, or mode of delivery. The

factors with the highest correlation to SaO_2 levels included an infant's postnatal age and activity level. Regarding postnatal age, SaO_2 readings increase with time over the first day of life. The location of the oximeter sensor influenced SaO_2 levels upon admission, but the measurements leveled by the time of discharge. At admission, SaO_2 readings from the foot were 0.3% lower than those recorded from the hand. However, throughout the first 24 hours, the levels from foot measurements increased at a faster rate (0.4%) than those monitored by the hand (0.2%) so that they were comparable at the second reading upon discharge. Therefore, there is no significance found in the SaO_2 levels recorded by one or the other location (Levesque et al., 2000).

Oxygenation and Behavior

Respiratory rates and heart rates vary based on an individual's behavioral state and general activity level (Ballard, 1988; Dreier & Wolff, 1972). Furthermore, Levesque et al. (2000) determined that postnatal age and activity are highly correlated and influential to the level of SaO_2. In this study, Levesque et al. (2000) compared SaO_2 levels during sleep to those recorded during fussy periods and again to those recorded during crying episodes. SaO_2 levels decreased 0.98% during the cry and 0.44% during fussiness when compared to sleep. However, the degree of sleep measured among these infants is not specifically noted. Within research, two categories of sleep are often differentiated. Paludetto, Robertson, Hack, Shivpuri, and Martin (1984) defined two types of sleep as *active* and *quiet* sleep states. According to these authors, *active sleep* presents with rapid eye movements visible under closed eyelids, frequent twitches of the face and limbs, and irregular respiration; *quiet sleep* is presented as the infant lies with her eyes closed, without eye or body movement other than an occasional startle, and

regular respiration. To reliably determine respiration patterns, rate, and SaO_2 levels, it is imperative that the child's activity and time of day be recorded to document regularity (Ballard, 1988).

Minute ventilation is another measurement that influences SaO_2 levels. Minute ventilation is the product of respiratory rate and tidal volume of the lung (Miller, Martin, Carlo, Fouke, Strohl, & Fanaroff, 1985). Thus, significant decreases in both the tidal volume of the lung and breathing frequency leads to a depressed generalized minute ventilation; a minute ventilation decrease may then lead to decreased oxygenation and increased carbon dioxide tension and result in apnea or bradycardia (Mathew, 1991). During feeding, minute ventilation decreases primarily through the continuous suck phase and less so in the intermittent phase. In contrast, nonnutritive sucking activities did not affect minute ventilation. This could be explained by the rare occurrence of swallowing during nonnutritive sucking compared to the 1:1:1 S: S: B ratio present within nutritive sucking activity (Koenig, Davies, & Thach, 1990).

Respiratory Disorders

Diseases of the respiratory system add complications to the feeding process because of generalized difficulty maintaining adequate breathing patterns. There is a wide range of disorders that may affect the fragile pulmonary system, and the need for supplemental oxygen in infancy is a predictor of such conditions. All aspects of the lung are compromised when an individual suffers from lung disease. This includes the mucosa, mucosal glands, smooth muscle, terminal air spaces, interstitium, and the pulmonary microvascular system (Ballard, 1988). Ballard (1988) states that any infant who required supplemental oxygen may develop subsequent respiratory dysfunction.

This criterion served as the basis of diagnosing infants with a chronic lung disease (CLD), which incorporated the spectrum of respiratory disorders including respiratory distress syndrome (RDS) and bronchopulmonary dysplasia (BPD).

Shennan, Dunn, Ohlsonn, Lennox, and Hoskins (1988) performed a study to determine whether infants diagnosed with BPD based on the supplemental oxygen requirement at 30 days postnatal age could be associated with later pulmonary abnormalities. This study found that children with pulmonary abnormalities were more likely to have required oxygen for an extended period. Twenty-one percent of the children analyzed with pulmonary abnormalities had not received oxygen supplements at 28 days postnatal. Therefore, 79% of the children received oxygen for more than 28 days. Through further analysis, Shennan et al. declare that an oxygen requirement at 36 weeks post-conceptual age has increased reliability in predicting later pulmonary abnormalities. Childhood presentation of lung disease may be characterized by inappropriate growth patterns, the possible hospitalization requirement in response to what was expected to be a benign upper airway infection, and a decreased response to upper airway treatment.

Chronic Lung Disease

The presence of CLD, coexisting instability of the lung, and subsequent dependence upon external breathing is related to immature development of the lung. In some instances, CLD is characterized by reduced amounts of surfactant produced within the lung (Ballard, 1988). Surfactant serves as an internal self-protection of the lung and guards against bacteria invading the alveolar sacs by strengthening the phagocytes of the lung. Decreased levels of surfactant causes damage to the interstitium of the lung,

decreases alveolar surface tension which, in turn, increases the risk of edema or collapse of the lung, and may lead to hypoxia (Ballard, 1988). Resulting is the diagnosis of CLD due to the compromised lung capacity to independently function adequately.

With CLD, it is possible to develop a vascular fluid leak. This increases the amount of time required for gas exchange to occur within the lung; the disorder subsequently worsens. A third prospect of immature lung development incorporates a defect in the structure and mobility of the cilia that lines the respiratory tract. This deficiency causes the development of chronic lung disease (Ballard, 1988).

Infants with CLD must exert a great level of energy to breathe, feed, or perform any activity. In order to achieve the task, the body consumes an increased amount of oxygen in comparison to other infants without CLD whom, therefore, require less effort to breathe. In turn, the high level of oxygen consumed by the infant reduces the oxygenation of the blood (Ballard, 1988). This would account for lower oxygenation recordings in children with respiratory disorders when compared to others without the impairment. Infants with CLD also require extra nutrients to develop and grow appropriately; however, as breathing expends a large amount of energy, it then takes an even greater amount to feed due to the coordination of breathing and swallowing. Thus, often these infants are undernourished and unable to grow normally (Ballard, 1988).

The respiratory severity score (RSS) integrates measurements of wheezing, carbon dioxide saturation, the requirement of oxygen to maintain an SaO_2 level above 92%, and gas exchange analysis (Frey & Freezer, 2001).

Respiratory Distress Syndrome (RDS)

RDS is a disorder of the pulmonary system affecting approximately 20% of all preterm infants. The risk of developing RDS increases as gestational age decreases with a 10% prevalence at 34-36 weeks and a greater than 60% incidence in infants less than 32 weeks gestation. Lung maturity decreases as gestational age decreases; therefore, lung maturity is also indirectly related to the incidence of RDS (Bernbaum & Batshaw, 1997). Infants with RDS will present with "grunting respirations" (Bernbaum & Batshaw, 1997, p. 120) because of the increased use of the abdomen to breathe.

One type of therapy for RDS involves pressurized oxygen supplements. In mild cases, continuous positive airway pressure (CPAP) is presented through a nasal cannula (two short tubes inserted in the nostrils) to produce pressure and encourage appropriate lung function. When infants have more severe forms of RDS, the patient is intubated and presented with positive end expiration pressure (PEEP) air and oxygen mixture. These two oxygen therapies are similar in nature, but the increased severity warrants increased contact with the lung (Bernbaum & Batshaw, 1997).

Another therapy technique for individuals with RDS is surfactant replacement therapy. This is used primarily for VLBW infants with RDS. This treatment may even be performed prior to the diagnosis of RDS as prevention of risk and severity of a lung disorder and improved prognosis. Minimized oxygenation and ventilation requirements improve the likelihood that a diagnosis of RDS will not progress into BPD.

Bronchopulmonary Dysplasia (BPD)

BPD is the development of a chronic lung disease caused by extended ventilation or supplemental oxygen (Northway, 2001; Ballard, 1988; Bernbaum & Batshaw, 1997).

Most infants who suffer from BPD were initially diagnosed with RDS (Ballard, 1988) and are preterm infants who were unable to be weaned from oxygen supplements (Bernbaum & Batshaw, 1997). The percentage of infants with RDS that progress to BPD has decreased from 75% in the early 1990s to 33% in 1997 as reported by Bernbaum and Batshaw. Major risk factors associated with BPD include preterm birth, supplemental oxygen or ventilator requirements, and respiratory failure (Northway, 2001). The risk for BPD development is further elevated if the infant has a history of asthma or allergies in the family (Ballard, 1988).

The majority of infants with BPD were ELBW or micropremies at birth, but 41% of preterm infants acquire BPD (Northway, 2001). Prevention strategies include the use of prenatal steroids to increase lung development, decrease the use of high concentration oxygen supplementation, regulate airway pressure, and the use of exogenous surfactant integrated through surfactant replacement therapy. According to Northway (2001), a diagnosis of BPD hinges on the infant meeting four criteria as follow: 1) use positive pressure ventilation within the first two weeks for a minimum of three days; 2) respiratory insufficiency signs last more than 28 days; 3) require supplemental oxygen for more than 28 days to keep the SaO_2 above 50mmHg; and 4) chest x-rays reveal characteristic findings of BPD. Chest x-rays are noted to expose interstitial thickening and a diffuse, cloudy, bilateral appearance of the lungs.

Inflammation causes the walls of the lungs to thicken; it is then more difficult to expand the alveoli due to thick walls and narrowing airways (Bernbaum & Batshaw, 1997). Gahler, Stallmach, Schwaller, Fey, and Tobler conducted a study in 2000 involving analysis of the cellular makeup of lung tissue affected by BPD. They reported

findings regarding the presence of IL-8 in all cell types of the BPD lung. This presence is significant because IL-8 is predominantly found in adult lungs affected by lung disorders. Therefore, the IL-8 findings in infant lungs substantiates a relationship between BPD and other adult pulmonary disorders (Gahler et al., 2000).

The severity of BPD is based on lung development, the presence of pulmonary complications and causes of the distress, and the extent to and levels at which oxygen supplementation was required (Northway, 2001). Therapy for BPD includes nutritional and oxygen supplements and a vaccination for respiratory syncytial virus (Northway, 2001). In addition, Bernbaum and Batshaw (1997) report that often ventilation is used for months after diagnosis. Diuretics are also recommended in order to increase the diameter of the airways and enhance the flexibility of the tissues. RDS and BPD often lead to further complications of the pulmonary system and compromise the life-sustaining mechanisms.

Conclusion

A review of literature discussing the preterm infant and issues of feeding and respiration related to development is presented. Criteria for an infant to be considered "preterm" is based upon the newborn's gestational age and is most often assessed using the New Ballard Score. Prematurity automatically places infants at increased risk for a variety of disorders. Studies of human anatomy disclose the overlapping functions of feeding and respiration placed upon the structures within the pharynx and larynx. Feeding development begins early during embryological development and extends into the postnatal weeks as newborns are adjusting to the environment and developing appropriate coordination of sucking, swallowing, and breathing necessary to achieve successful oral

feeding. Major findings regarding this overlap include the documentation that it is impossible to breathe and swallow simultaneously.

Since breathing may not occur during a swallow, SaO_2 levels in the blood decrease during feeding. SaO_2 is routinely monitored by pulse oximetry, a noninvasive machine that records oxygen levels via infrared light readings. Despite the noninvasive nature, pulse oximeters carry risks of adverse effects from poor application and monitoring of the probe site. SaO_2 is compromised during feeding and further by respiratory diseases. Chronic lung dysfunction incorporates a spectrum of pulmonary disorders including RDS and BPD. Each of these is linked to the use of supplemental oxygen early in life and damage to lung tissues.

This literature review addresses aspects of feeding, respiration, SaO_2, and factors that influence each of these domains. Findings substantiate the need for this study to answer the following:

1) What is an average degree of SaO_2 change during feeding compared to that during rest in the population of full-term infants?
2) What is an average degree of SaO_2 change during feeding compared to that during rest in the population of preterm infants with respiratory anomalies?
3) What is an average degree of SaO_2 change during feeding compared to that during rest in the population of preterm infants without respiratory anomalies?
4) How do the changes in SaO_2 during feeding compare among full-term infants and to those who are preterm with and without respiratory anomalies?

5) To what degree are full-term infants able to recover from altered SaO_2 during feeding compared to preterm infants with respiratory disorders and those without respiratory disorders?

CHAPTER III
METHODOLOGY

Research Design

Thirty infants were involved in this study and divided into three equal groups based on gestational age and/or respiratory status as follows: 1) full-term infants (≥37 weeks gestations) without respiratory anomalies (control group); 2) preterm (<37 weeks gestation) infants without respiratory anomalies; and 3) preterm infants with respiratory anomalies. Approval from the Institutional Review Board was achieved, and consent was gained from a parent of each subject prior to collecting data.

To determine if there is a normal degree of oxygen desaturation that occurs during feeding, subjects were monitored during feeding and sleep activity. The extreme difference in activity levels between feeding and sleeping offers the greatest insight to the risk of desaturation possibly occurring between activities. The subjects were monitored using Hewlett Packard monitors and Nellcor pulse oximeter sensors, already in place in the nurseries. Data from this research presents SaO_2 documentation regarding normal, healthy full-term infants and preterm infants with and without respiratory anomalies. This information is expected to help guide the caregivers in the nurseries regarding the status of an infant's respiratory stability during the vulnerable activity of feeding.

Goals of this research are to focus on the following research questions:

1) What is an average degree of SaO_2 change during feeding compared to that during rest in the population of full-term infants?
2) What is an average degree of SaO_2 change during feeding compared to that during rest in the population of preterm infants with respiratory anomalies?
3) What is an average degree of SaO_2 change during feeding compared to that during rest in the population of preterm infants without respiratory anomalies?
4) How do the changes in SaO_2 during feeding compare among full-term infants and to those who are preterm with and without respiratory anomalies?
5) To what degree are full-term infants able to recover from altered SaO_2 during feeding compared to preterm infants with respiratory disorders and those without respiratory disorders?

Instrumentation

All infants studied were monitored by the Nellcor sensor and the Hewlett Packard monitor for the oximeter. The subjects within groups 2 and 3 of this study had their SaO_2 monitored by pulse oximeters at all times as is regular procedure in the NNICU and Level 2 nursery. The data collected through this study will document the SaO_2 readings at various times.

SaO_2 Readings measured by pulse oximetry are considered accurate and reliable because they closely correlate with those analyzed by arterial blood gas laboratories provided that the subject does not have a peripheral vascular disorder and the SaO_2 is

maintained greater than 70% (McConnell, 1999). In accordance with the subject exclusion criteria, the sample is not affected by the outlying factors.

Sample Selection

All infants participating in this study were patients at the Medical University of South Carolina Hospital and had no history of any genetic, cardiac, or neurologic disorder. The subjects consist of the first ten infants to meet criteria for each group as each infant admitted to the nursery throughout the summer of 2002 was screened to determine his or her eligibility. The control group involved a sample of healthy, normal full-term infants under care in the normal newborn nursery. The sample group of preterm, normally developing infants was cared for in either the Level 1 (normal newborn nursery) or the Level 2 nursery and had no history of respiratory conditions or necessary resuscitative efforts. The third group of subjects includes preterm infants who had current or a history of respiratory conditions and were patients cared for in the Medical University of South Carolina NNICU or Level 2 nursery. Most commonly, these infants had been diagnosed with RDS or BPD. No child was excluded on the basis of gender or race. Graph 1 presents demographic and medical information for each participating subject.

Graph 1

Subject Demographics

Group #	Subj #	Race	Sex	Gest. Age wks-birth	Gest. Age wks-data	Cardiac / Genetic	Respiratory Conditions
1	1	B	M	39	39	None	None
1	2	B	F	40	40	None	None
1	3	B	F	39	39	None	None
1	4	W	F	39 3/7	39 3/7	None	None
1	5	B	F	40 4/7	40 4/7	None	None
1	6	W	M	39 3/7	39 3/7	None	None
1	7	W	F	39	39 2/7	None	None
1	8	B	F	38	38 1/7	None	None
1	9	B	F	40 4/7	40 5/7	None	None
1	10	B	F	40	40	None	None
2	1	B	F	32 2/7	34 4/7	None	None
2	2	B	F	32 2/7	33 2/7	None	None
2	3	B	F	29	33	None	None
2	4	B	F	33 5/7	35 3/7	None	None
2	5	W	F	35	35	None	None
2	6	W	F	35 2/7	35 2/7	None	None
2	7	W	M	35 2/7	35 2/7	None	None
2	8	W	F	35 2/7	35 2/7	None	None
2	9	B	M	33 3/7	34	None	None
2	10	W	F	36 4/7	36 4/7	None	None
3	1	W	M	32	35 2/7	None	RDS: NCPAP-->RA
3	2	W	M	28 3/7	32 3/7	None	CPAP, on O2
3	3	B/H	M	25	39 1/7	None	RDS, BPD, h/o desats
3	4	B	M	28 4/7	32 3/7	None	on O2
3	5	W	M	28 2/7	37 3/7	None	Survanta x2, NCPAP
3	6	W	F	27 5/7	35 2/7	None	h/o desats, on O2
3	7	W	F	28	35 6/7	None	Survanta, intubation
3	8	B	M	29 6/7	35 3/7	None	mild RDS, resolved
3	9	W	M	32 5/7	33 2/7	None	RDS, BPD, on O2 nc
3	10	B	F	29	36 4/7	None	RDS, NC-->RA

Data Collection

For each preterm infant in the NNICU, data was recorded during sleep, feeding, and post-feeding intervals. Feeding studies were exclusively bottle-feedings presented by the nurse or caregiver present at the time. Post-feeding studies incorporated readings at 5, 10, and 15 minutes after the completion of the feeding session. Three sessions of each activity were studied. Each sleep session consists of three minutes of SaO_2 documentation. Each feeding session monitored one mealtime, but the duration of each varied based on the individual's feeding speed and amount. Levels read on the monitor were recorded in 15-second intervals.

The full-term infants were hooked to the oximeter upon sleeping and feeding for the intervals equal to the sessions documented for the preterm infants. Recordings were made in the same fashion as performed on each subject in the preterm infant samples. Post-feeding sessions were also recorded at 5, 10, and 15-minute intervals after the feeding completion. Only infants who are bottle-fed were considered eligible for this study in any group. Varying from the data of the preterm subjects, only one session at each activity level was recorded for the full-term infants due to the hospital protocol and rapid discharge rate for full-term babies. These infants were monitored solely within the first 24 hours of life. Appendix C presents examples of data collection sheets.

Data Analysis

Independent variables associated with this study include each infant's gestational age at birth, gestational age at the time of data collection, respiratory status, gender, and race. Dependent variables comprise each infant's SaO_2 levels during each of sleep, feeding, and post-feeding activities. The sample includes three groups of infants.

Subjects of group 1 compile the control group of healthy full-term infants. Group 2 subjects are preterm infants without respiratory disorders; group 3 consists of the preterm infants with respiratory anomalies. Analysis of the data was performed using an analysis of variance (ANOVA) with multiple comparisons such that the levels of SaO_2 were compared according to the differences exhibited between sleep and feeding within each group of subjects.

Measurements of SaO_2 were recorded in 15-second intervals during each session. Sleep data values were averaged over the cumulative nine minutes recorded for the preterm infants and three minutes for the full-term subjects. All the sleep values were averaged together to avoid any internal bias from individual sleep sessions because there was no control over the time of occurrence within the sleep cycle or the time of day at data collection. This single SaO_2 value for each subject represents the average saturation exhibited by the individual during sleep.

For feeding sessions, SaO_2 recordings were also made in 15-second intervals. However, several pauses for burping or repositioning occurred during many of the feeding sessions. Therefore, these periods are depicted as no SaO_2 values were recorded, thus creating a break in the data graphs. The values from the 5, 10, and 15-minute intervals after feeding were also recorded to examine the general tendency of SaO_2 recovery. Within each feeding session, one value was identified as representing the maximum change in SaO_2 from Time 0. Each subject's single feeding SaO_2 value was calculated to be the average of his or her three maximum change values (1 per session).

The Levene test of homogeneity was used to assess the ANOVA model assumption of equal variance. One-way analysis of variance for three groups of equal

number was used to test the null hypothesis of equal means. The Bonferroni method would be used for post hoc pairwise multiple comparisons if ANOVA identified a difference among the groups. Sample size calculations indicated that 10 subjects per group would yield 80% power (alpha = 0.05) to detect an effect size of 0.36, where effect size is defined to be the variance of the means divided by the common standard deviation (SD). Common SD and variance of the means were estimated based on expected values.

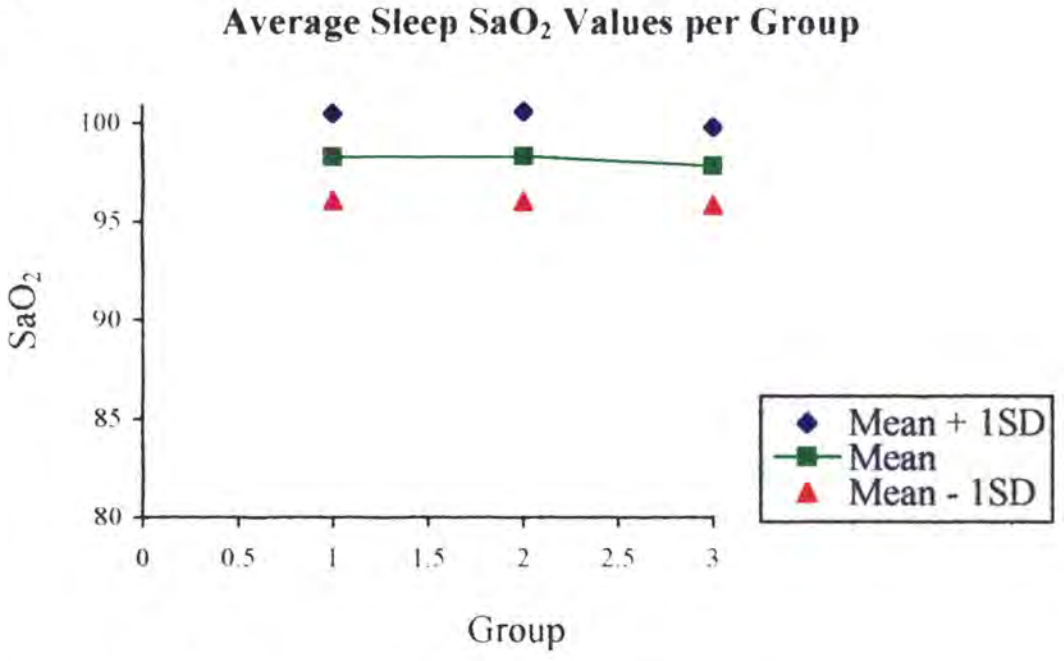
Analysis of the data involved several distinct values. For the sleep information, the single average value represents all data. In determining the changes in SaO_2 during feeding, we identified a value for each subject representing the maximum change in SaO_2 during each feeding session in comparison to the SaO_2 value at Time 0. This difference was analyzed relative to the initial feeding values as this shows the actual change in SaO_2 during the feeding session. The actual change in SaO_2 values during the feeding is then compared directly to the average sleep SaO_2 recordings.

CHAPTER IV
RESULTS

Sleep

Average sleep values for each group were determined as follow (with SD in parentheses): a) Group 1, 98.290 (2.229); b) Group 2, 98.320 (2.285); c) Group 3, 97.830 (1.989) as shown below in Graph 2.

Graph 2



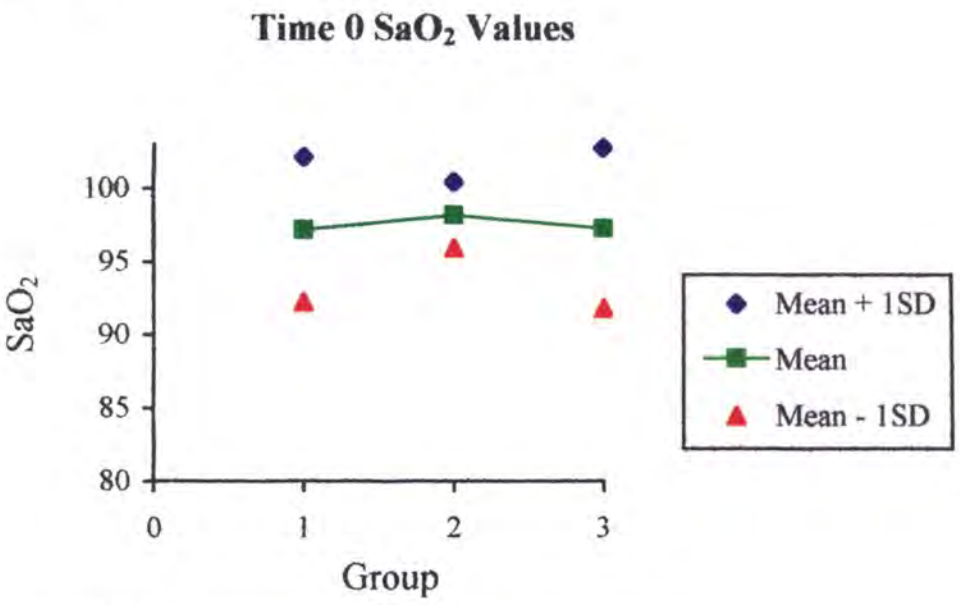
Graph 2. SaO_2 represents oxygen saturation percentage.

Feeding

The Levene test of homogeneity was used to assess the ANOVA model assumption of equal variance. At the 0.05 level, the hypothesis of equal variances across the three groups was not rejected ($p = 0.205$). The null hypothesis for the ANOVA is that of equal means. The ANOVA test concludes no statistical significant difference between

the means was found at the 0.05 level ($p = 0.483$). Average sleep values for each group were determined as follow (with SD in parentheses): a) Group 1 is 97.200 (4.962); b) Group 2, 98.180 (2.261); c) Group 3, 97.300 (5.462) as depicted in Graph 3.

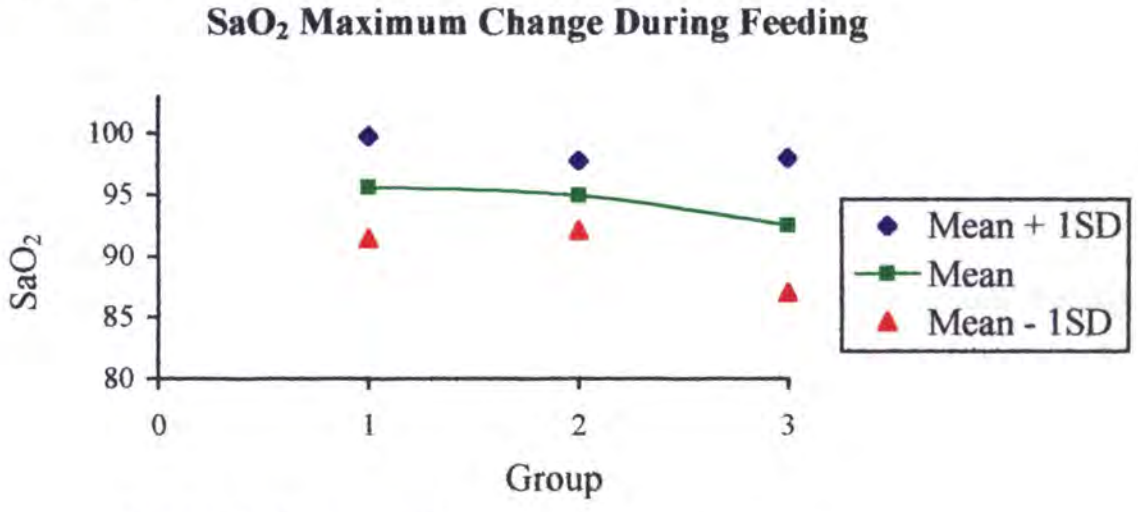
Graph 3



Graph 3. SaO_2 represents oxygen saturation percentage.

Average SaO_2 value representing the average maximum change during feeding values for each group were determined as follow (with SD in parentheses): a) Group 1, 95.600 (4.169); Group 2, 94.930 (2.847); Group 3, 92.500 (5.471) and is revealed through Graph 4.

Graph 4

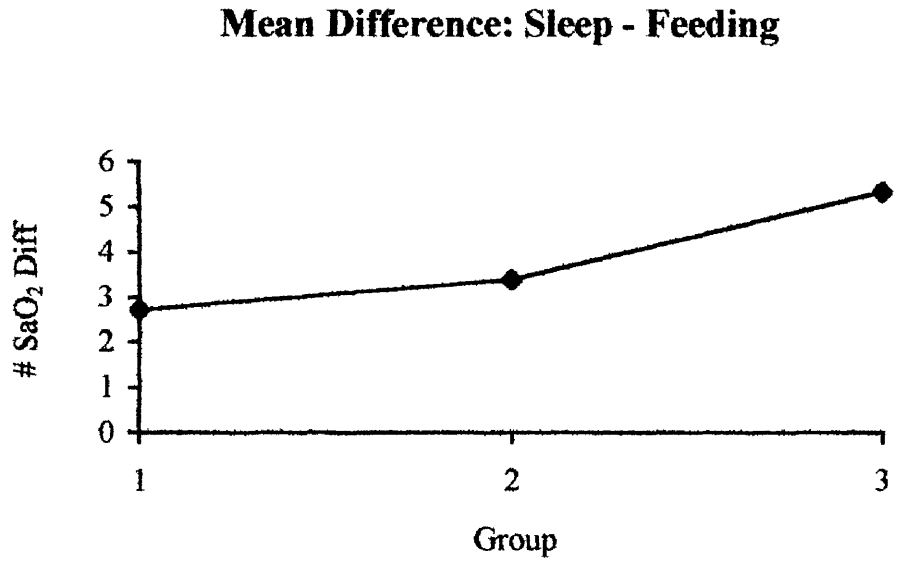


Graph 4. SaO_2 represents oxygen saturation percentage.

Comparison

A one-way ANOVA was performed on the data representing each group's *difference between the average sleep value and the average maximum change during* feeding value. From these values, the difference in the means (sleep - maximum change) was calculated and compared through an ANOVA. At the 0.05 level, the hypothesis of equal means across the three groups was not rejected ($p=0.483$). Graph 5 displays the mean differences recorded for each group.

Graph 5



Graph 5. SaO_2 represents oxygen saturation.

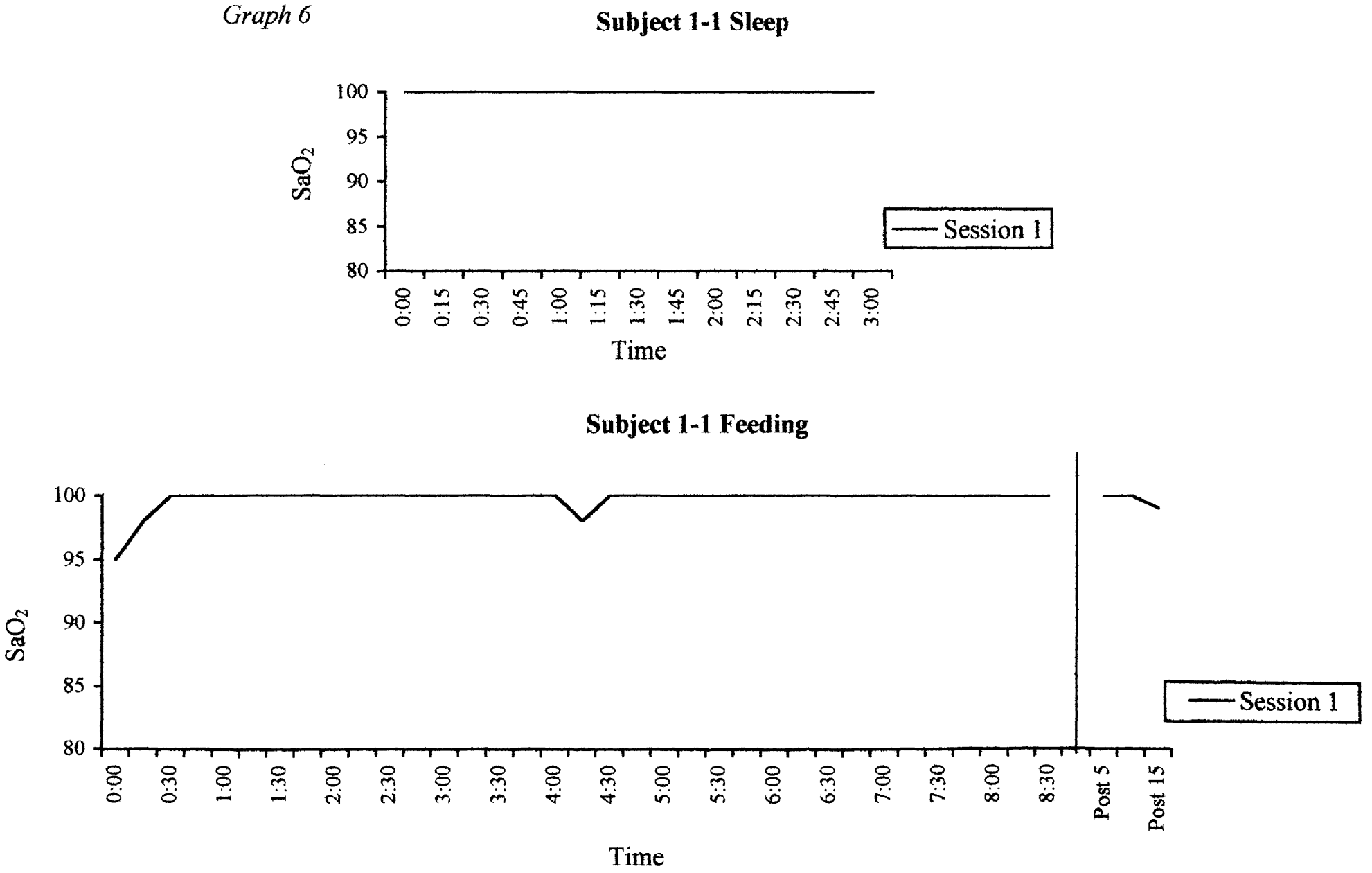
Recovery

All subjects exhibited appropriate recovery from SaO_2 changes. Each infant established an SaO_2 value of 100% within 15-minutes following the feeding session.

Individual Subject Data

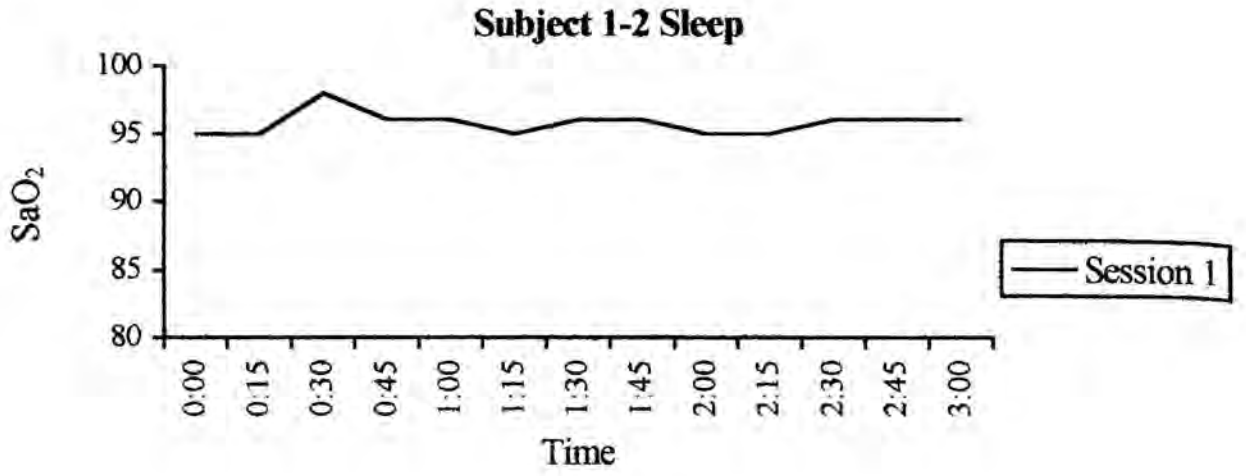
Graphs 6-35 display SaO_2 values recorded during both sleep and feeding sessions for each infant. Graph titles denote each individual's group and subject number within that group.

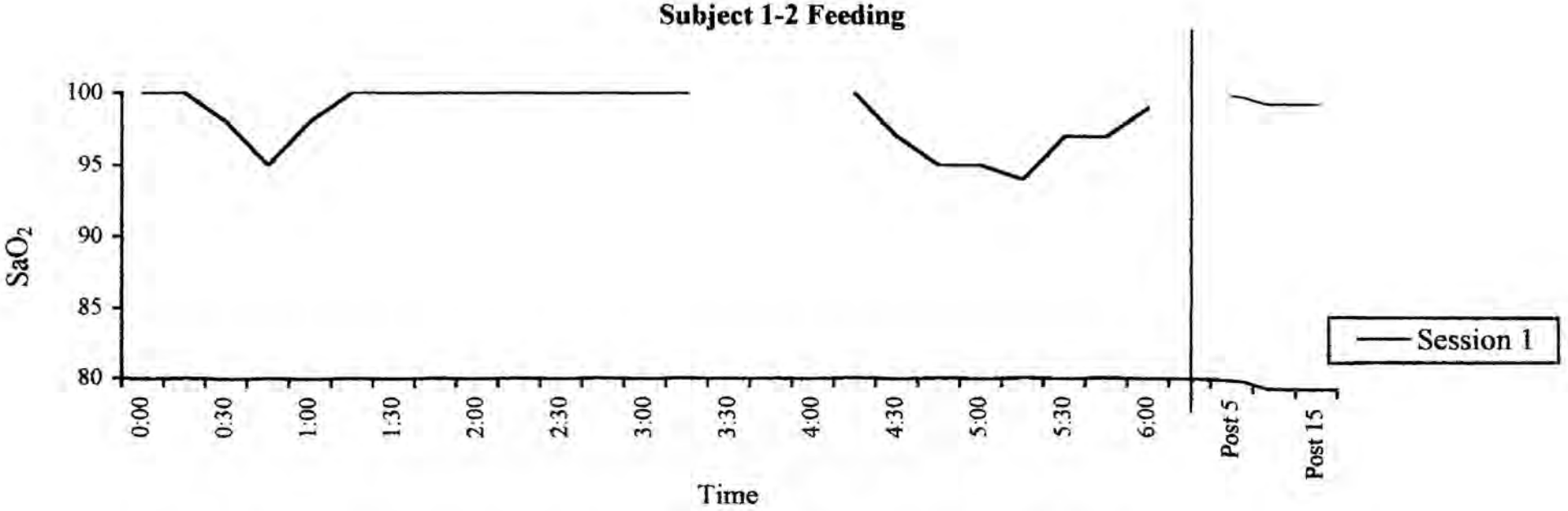
Graph 6



Graph 6. SaO_2 represents oxygen saturation percentage. Time represents minutes:seconds of session.

Graph 7

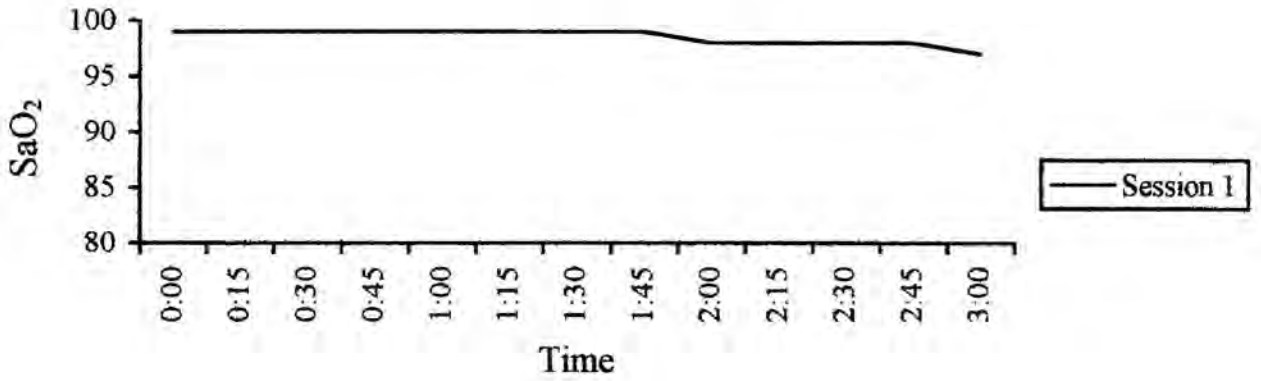




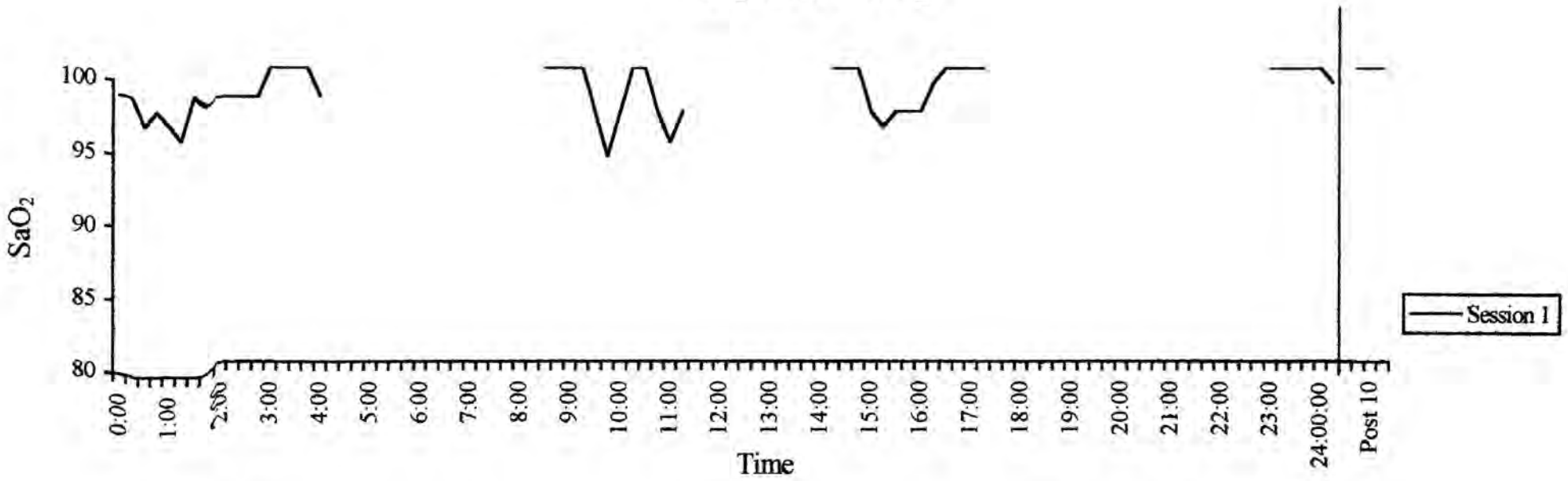
Graph 7. SaO_2 represents oxygen saturation percentage. Time represents minutes:seconds of session.

Graph 8

Subject 1-3 Sleep

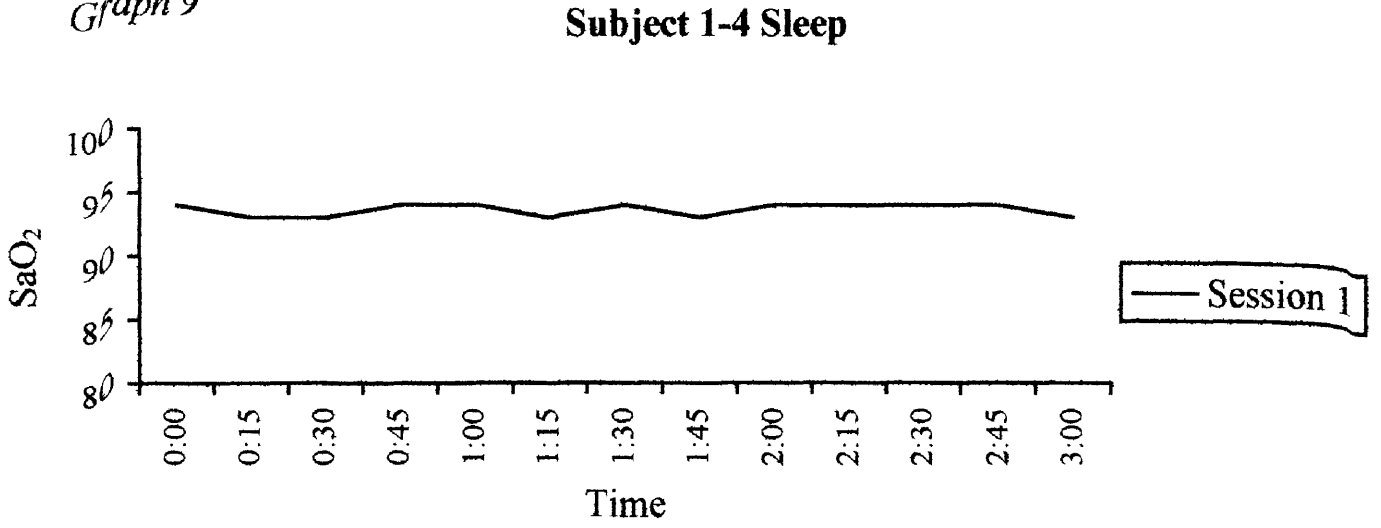


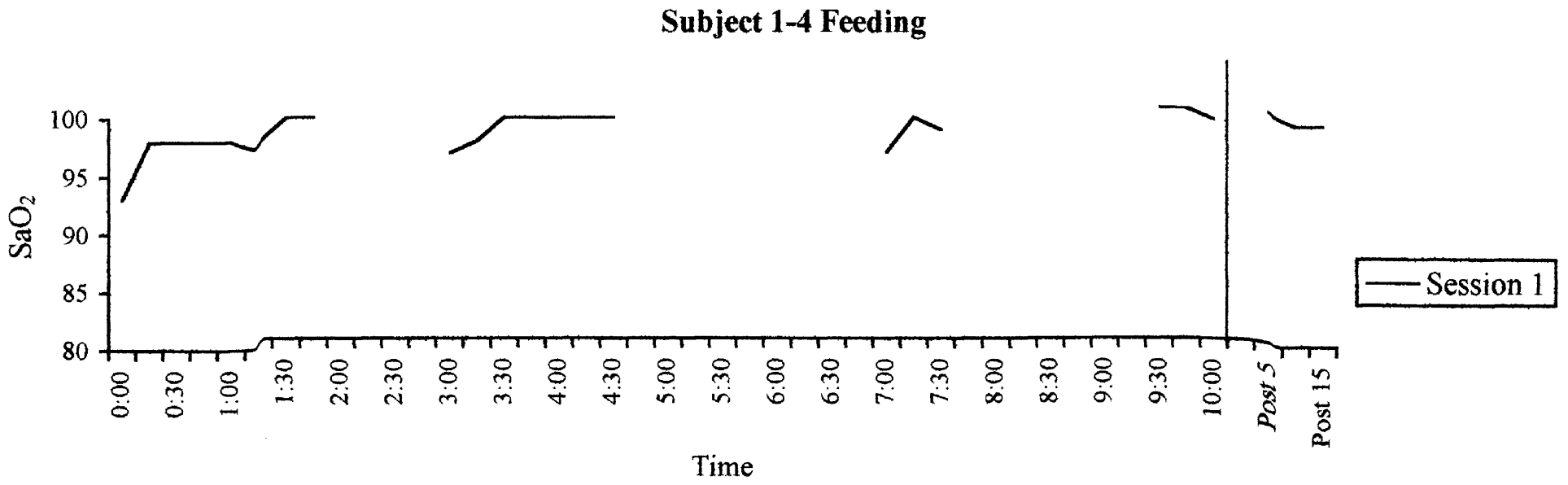
Subject 1-3 Feeding



Graph 8. SaO_2 represents oxygen saturation percentage. Time represents minutes:seconds of session.

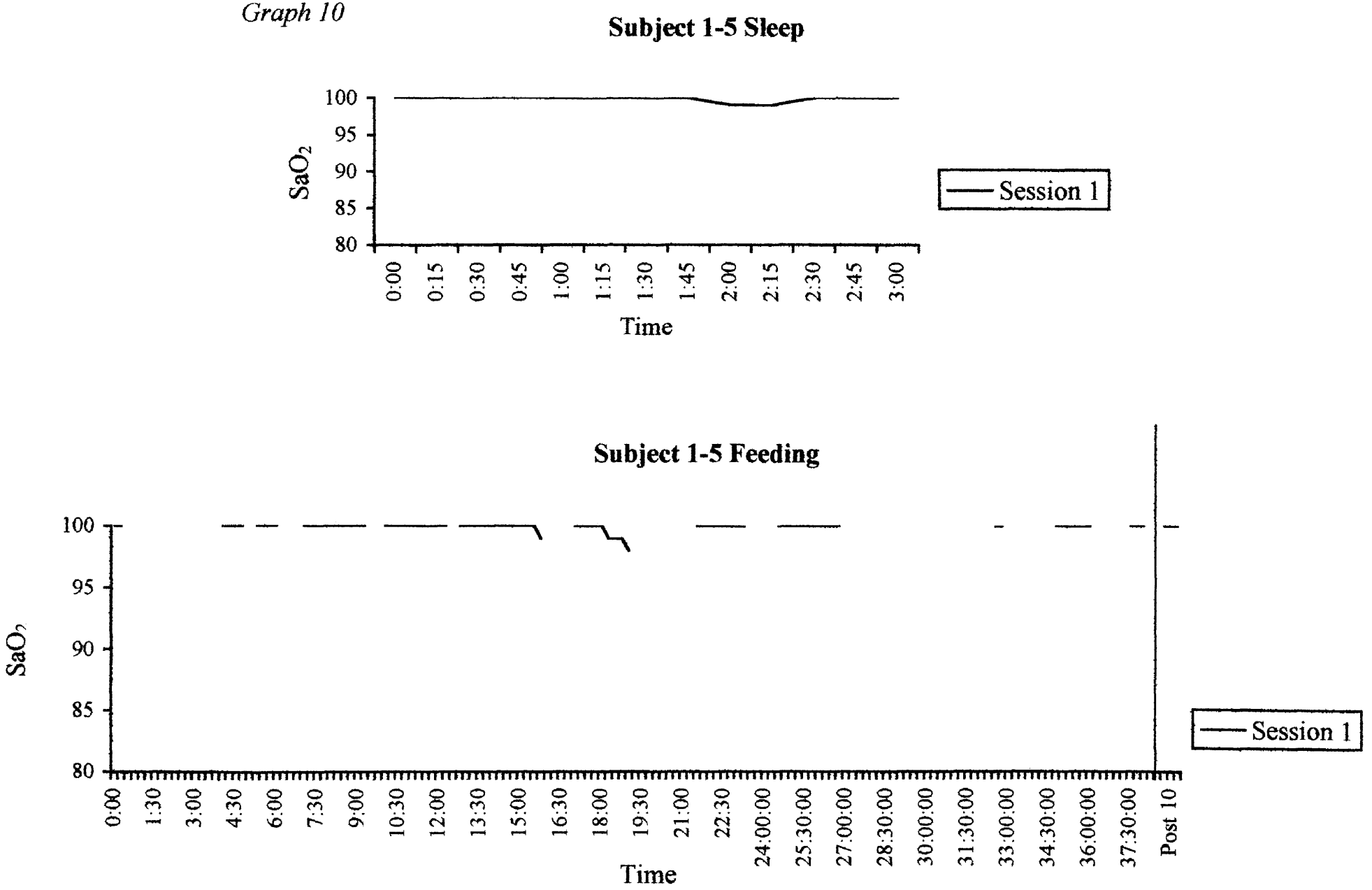
Graph 9





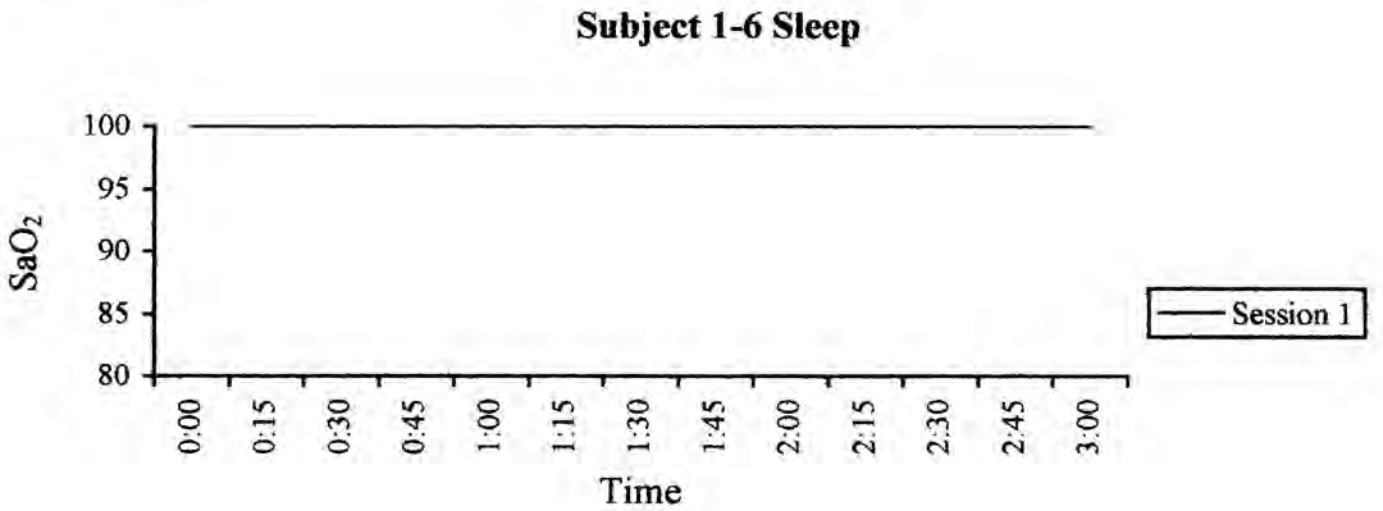
Graph 9. SaO_2 represents oxygen saturation percentage. Time represents minutes:seconds of session.

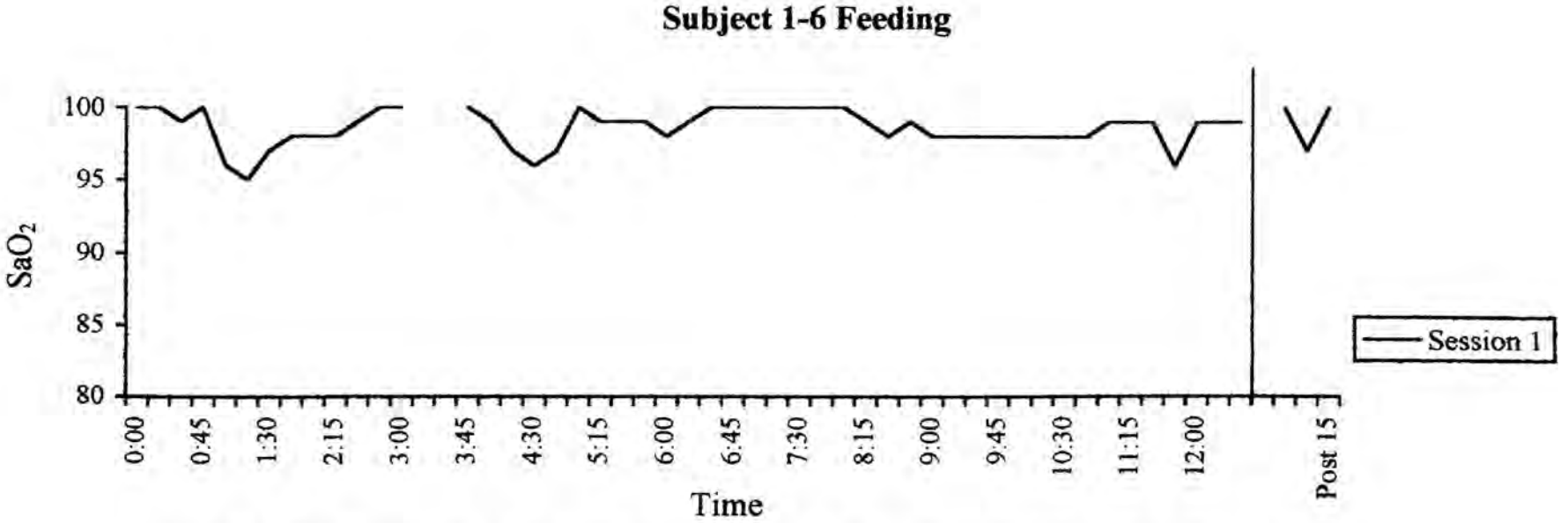
Graph 10



Graph 10. SaO_2 represents oxygen saturation percentage. Time represents minutes:seconds of session.

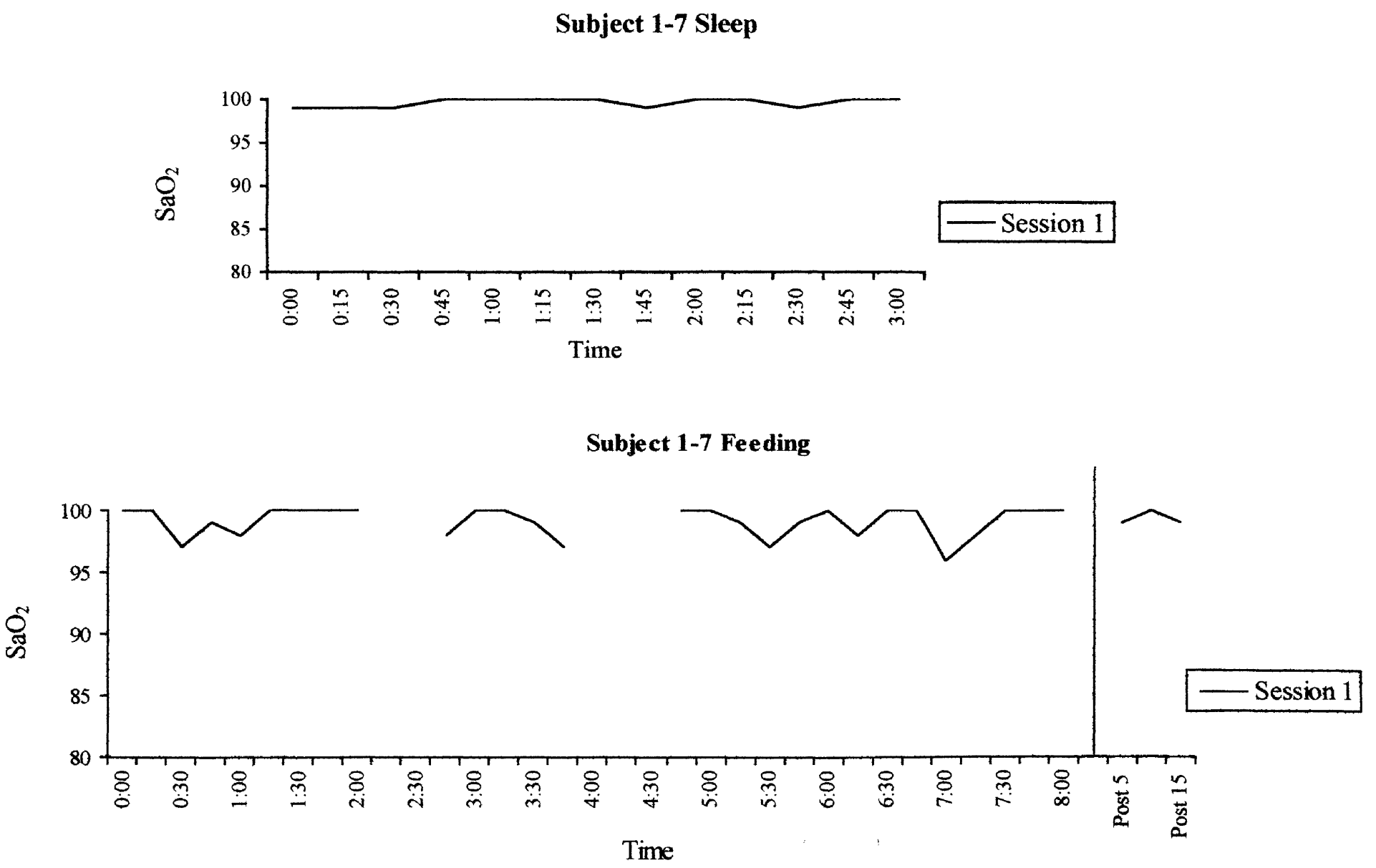
Graph 11





Graph 11. SaO_2 represents oxygen saturation percentage. Time represents minutes:seconds of session.

Graph 12



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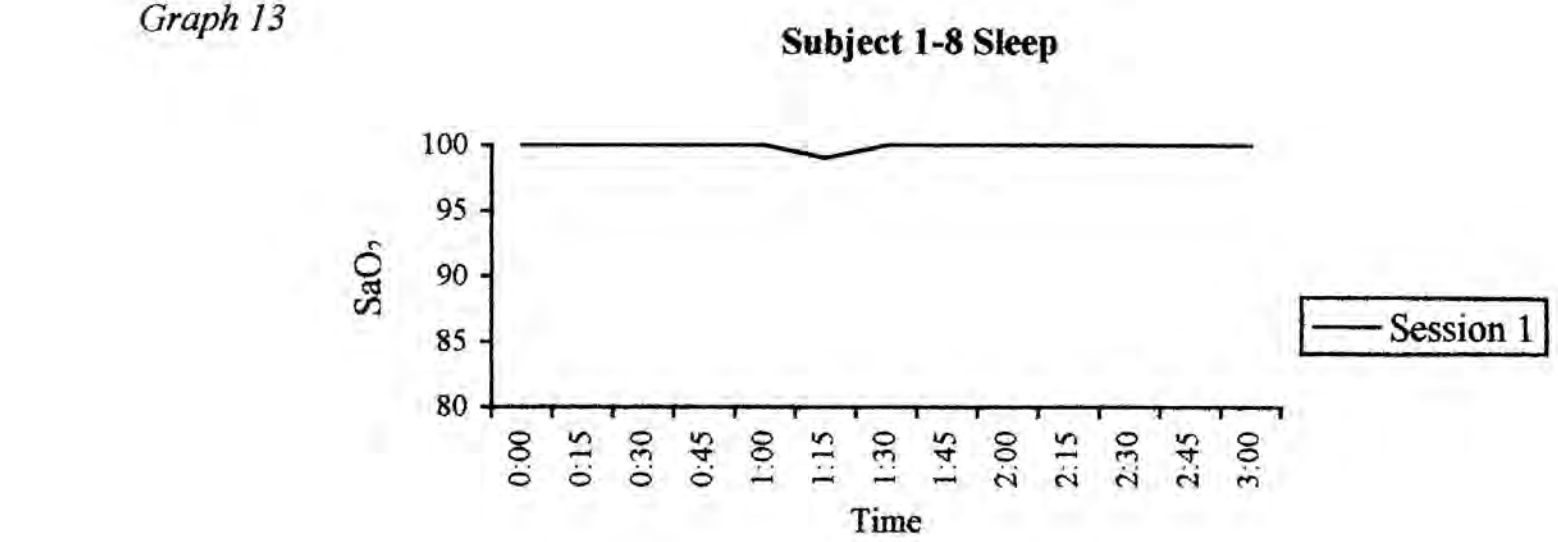
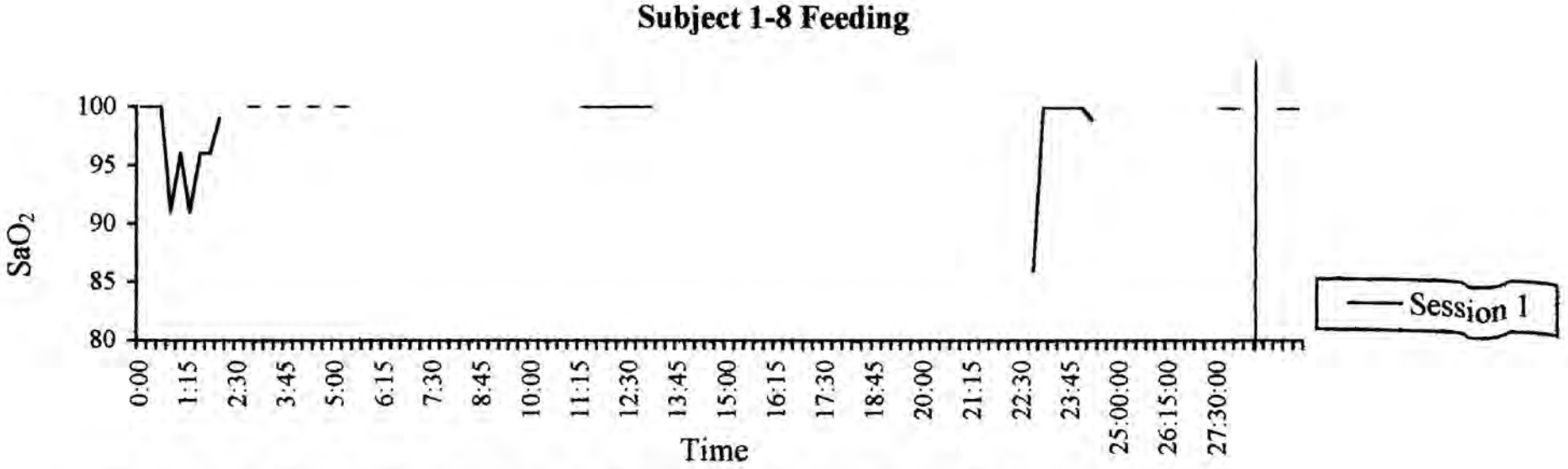
Graph 13





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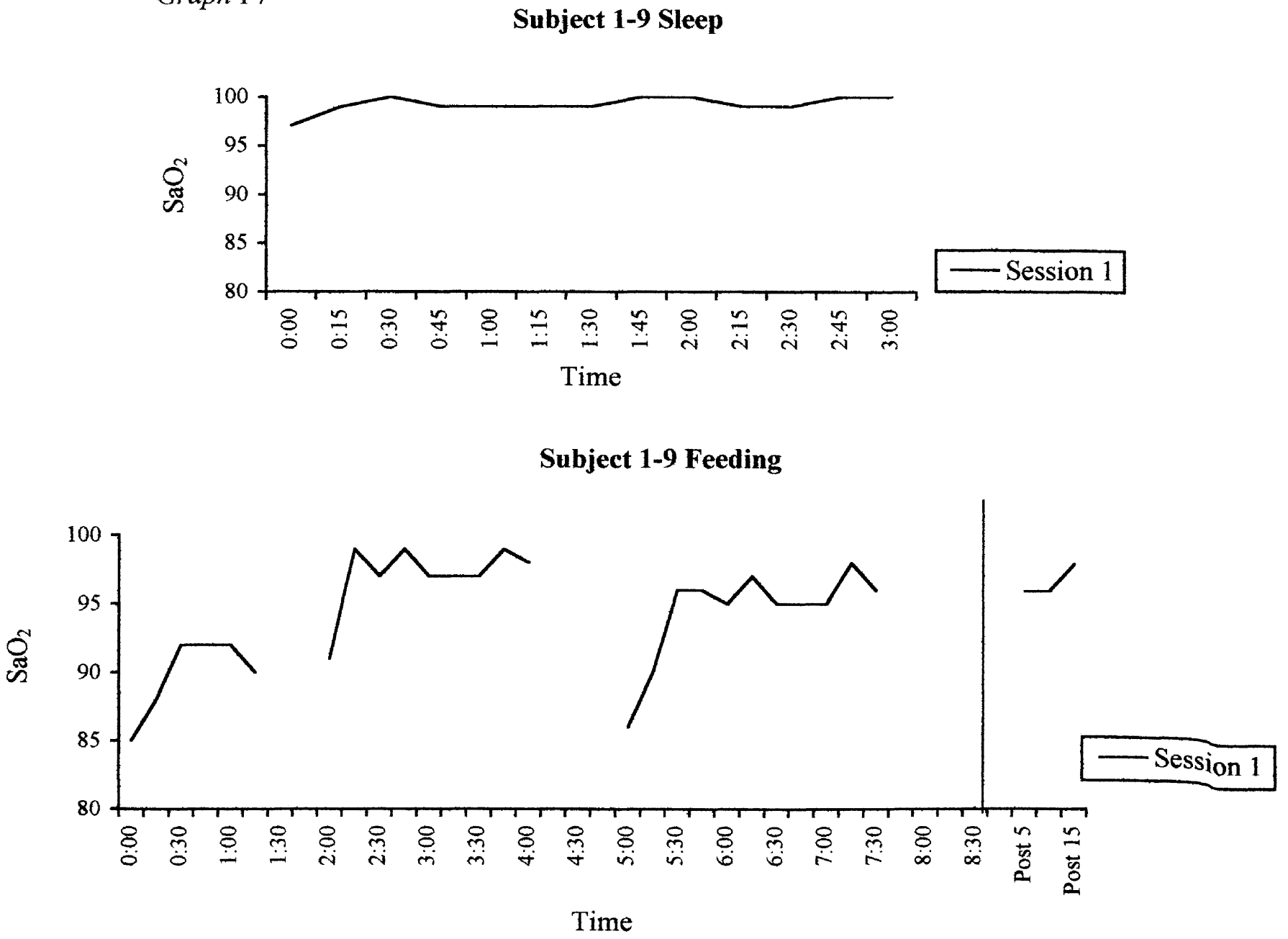
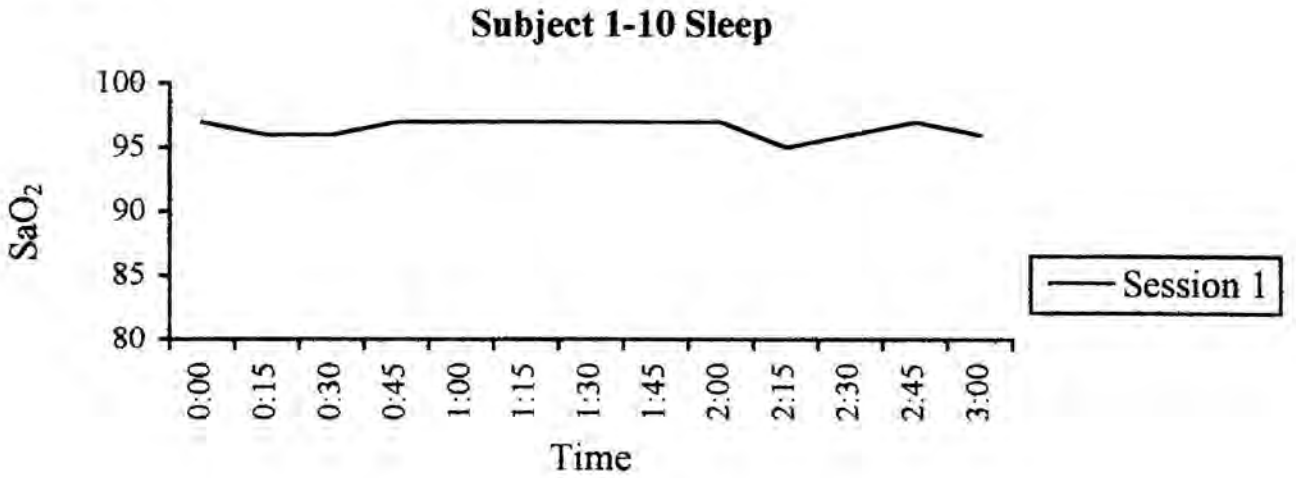
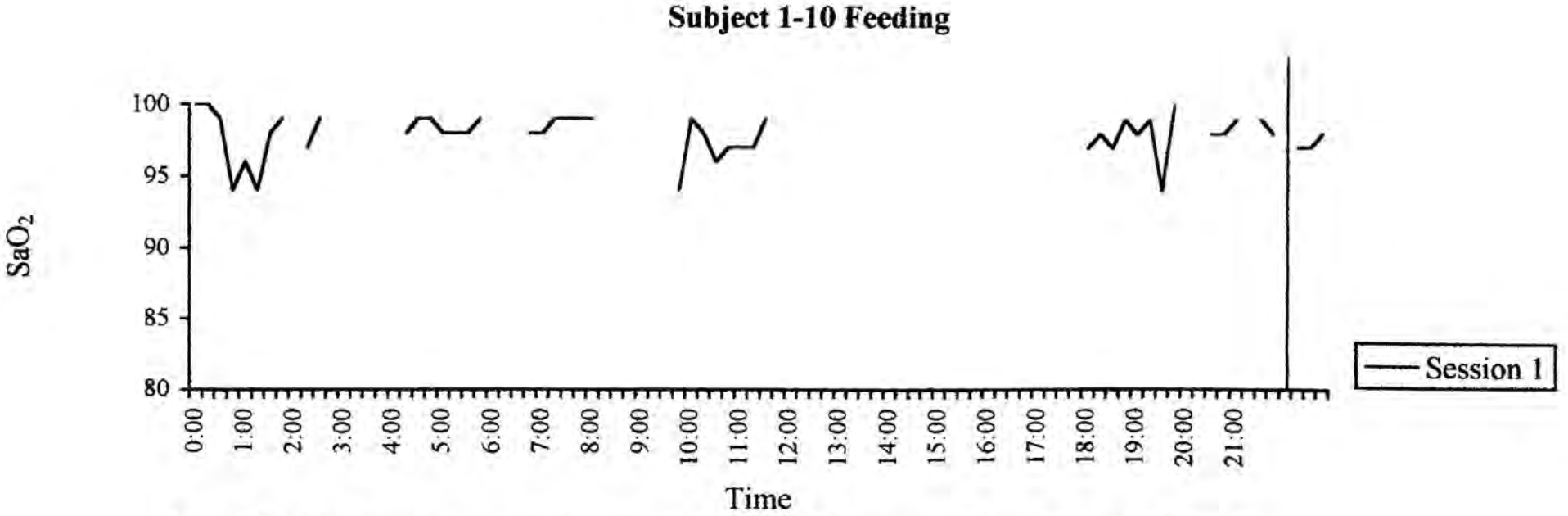
Graph 14



Graph 14. SaO_2 represents oxygen saturation percentage. Time represents minutes:seconds of session.

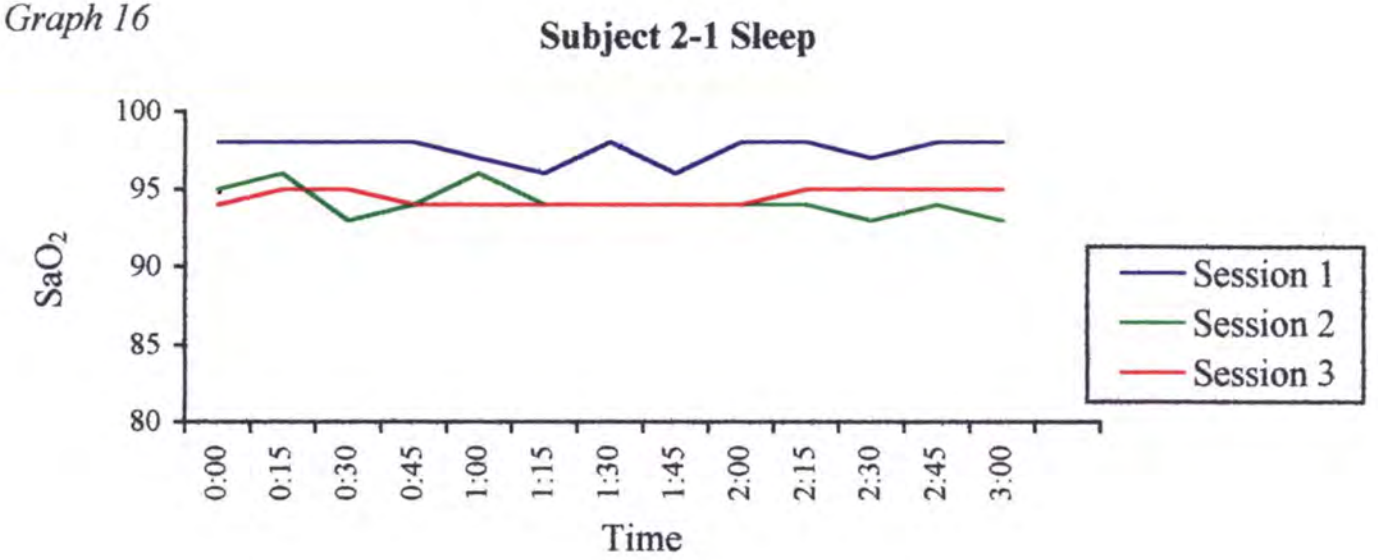
Graph 15

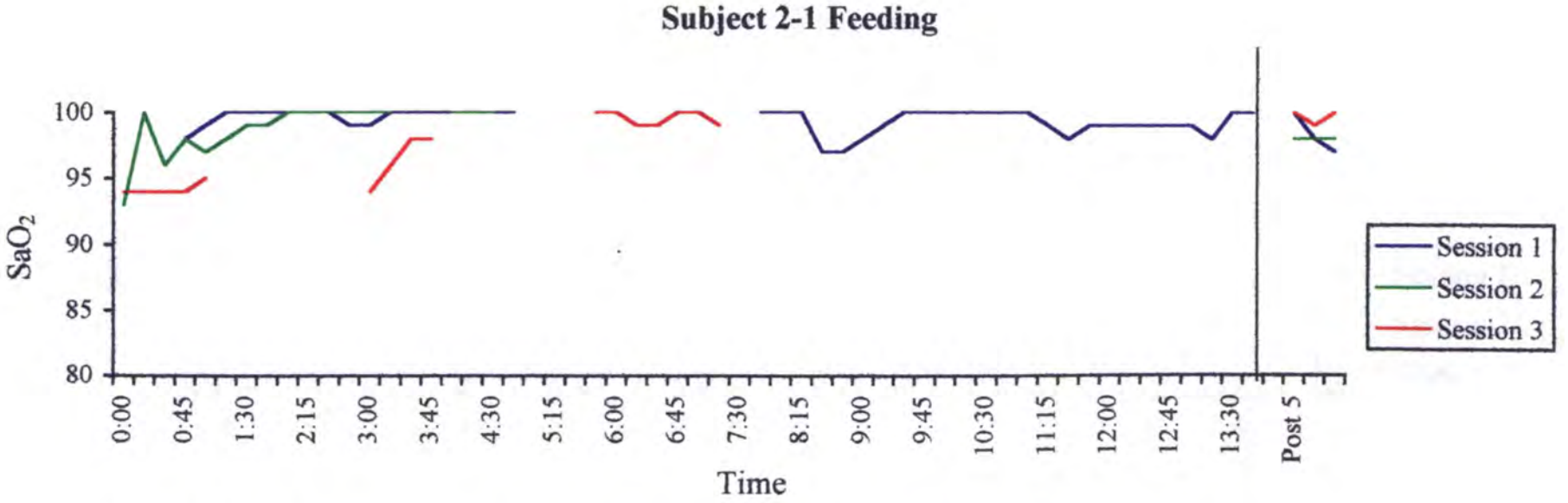




Graph 15. SaO_2 represents oxygen saturation percentage. Time represents minutes:seconds of session.

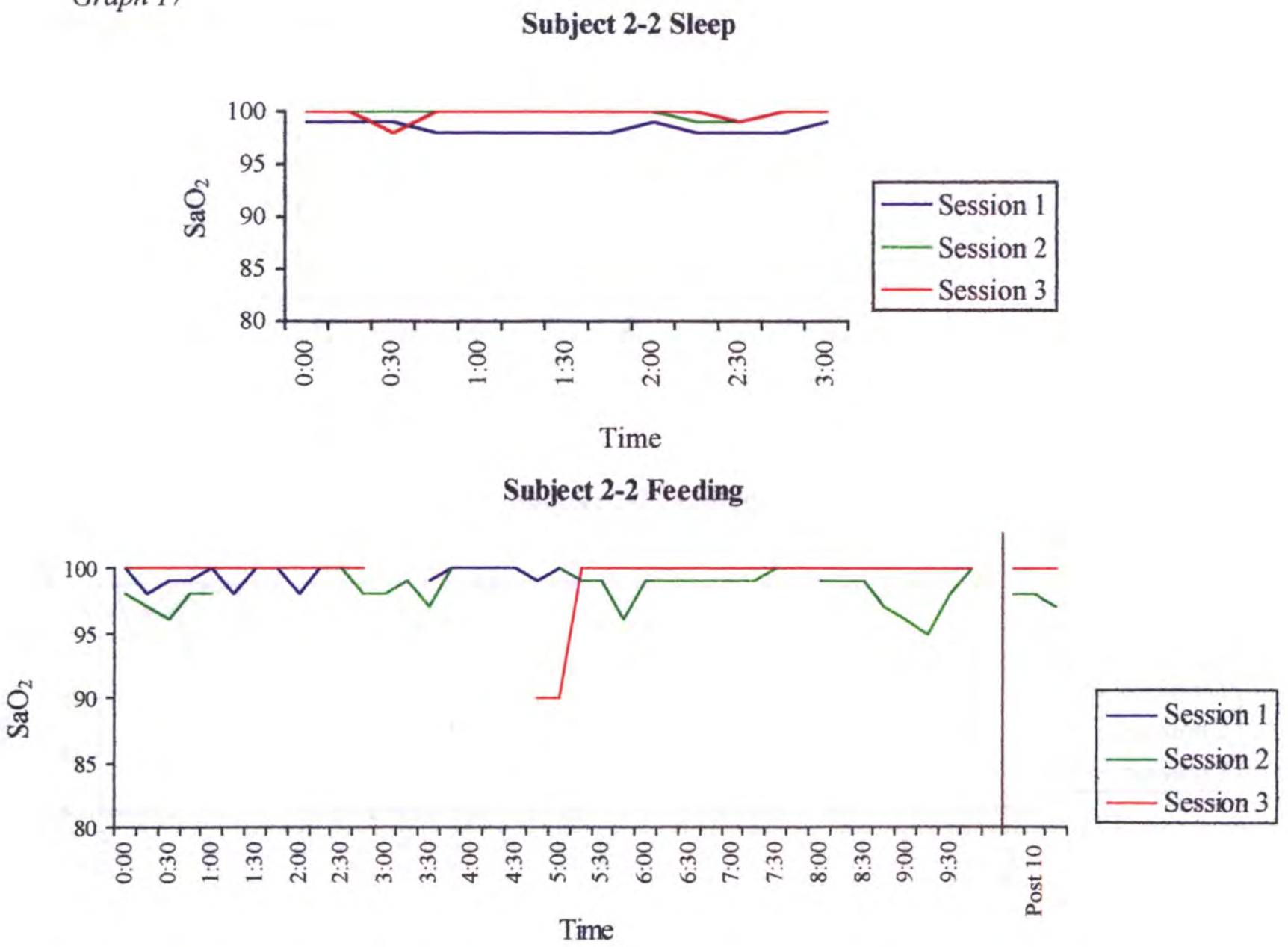
Graph 16





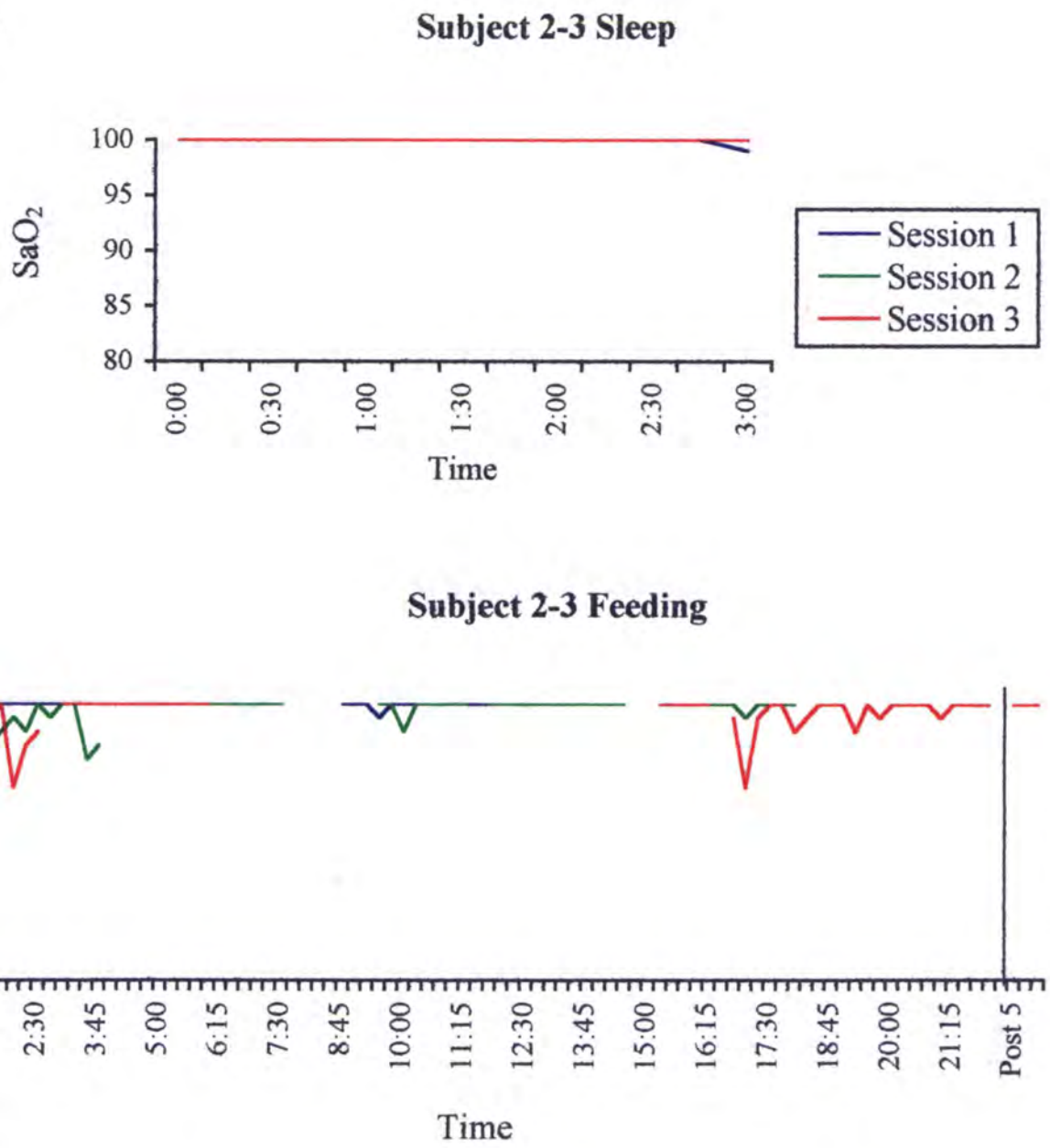
Graph 16. SaO_2 represents oxygen saturation percentage. Time represents minutes:seconds of session.

Graph 17



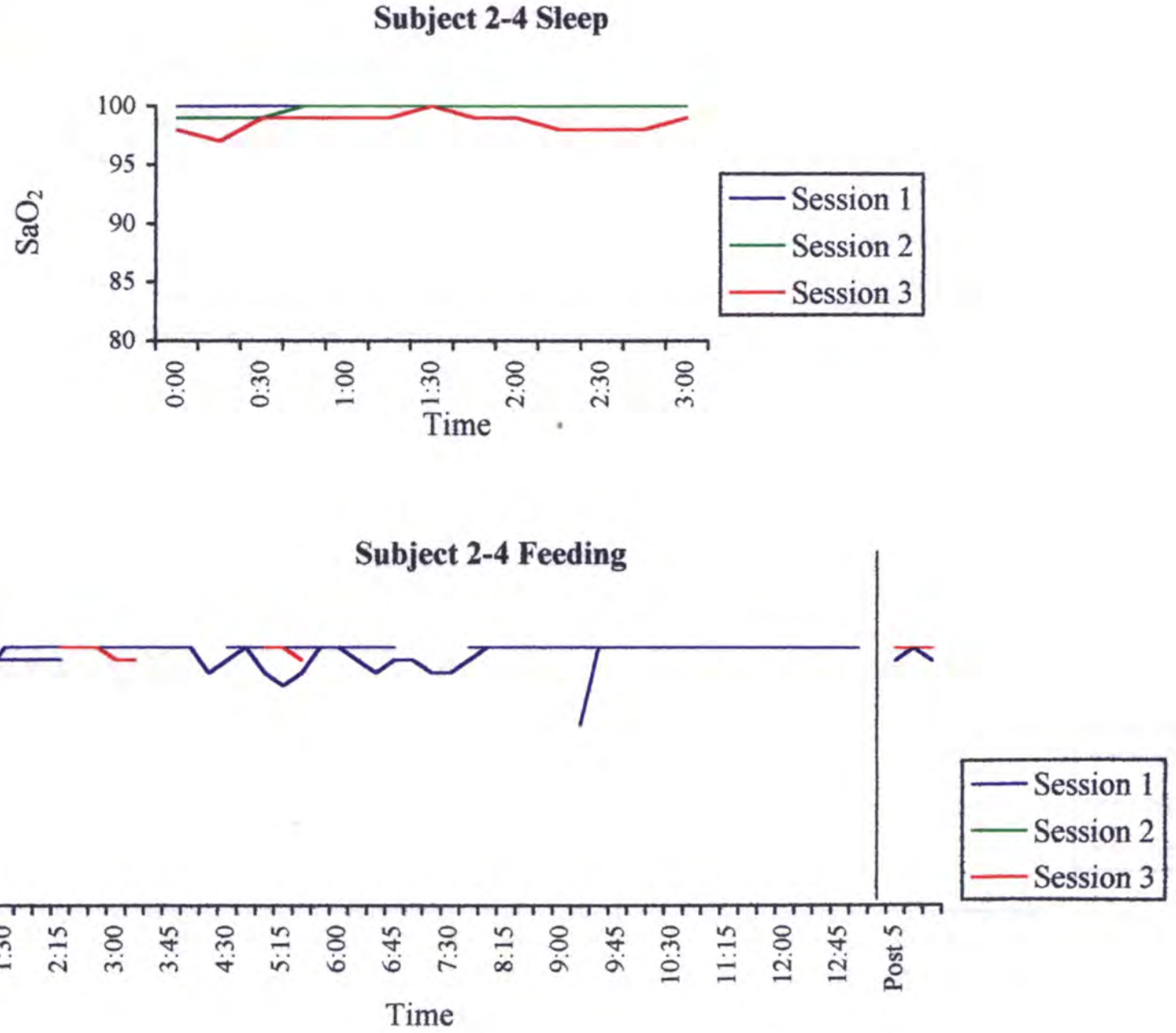
Graph 17. SaO_2 represents oxygen saturation percentage. Time represents minutes:seconds of session.

Graph 18



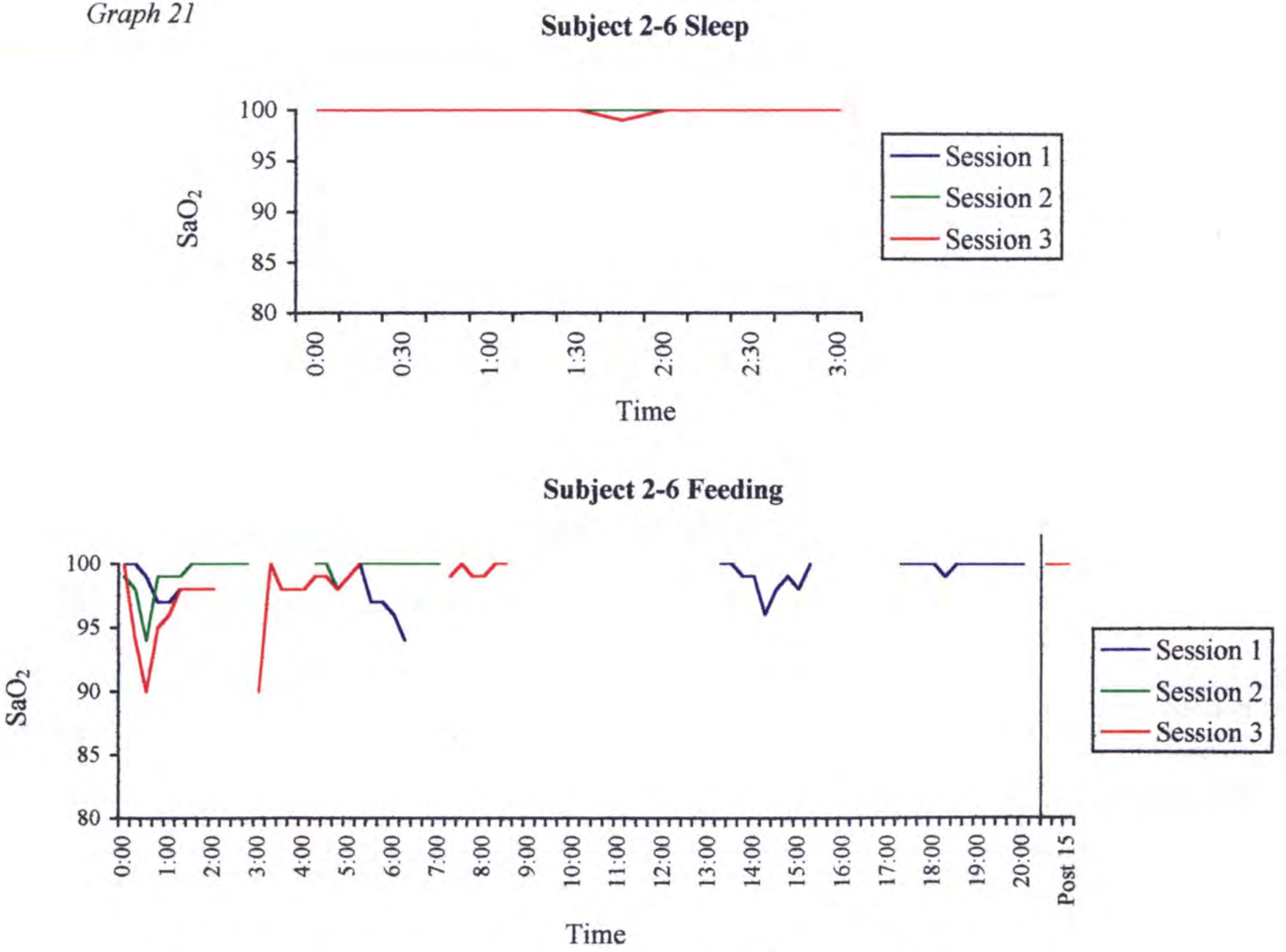
Graph 18. SaO_2 represents oxygen saturation percentage. Time represents minutes:seconds of session.

Graph 19



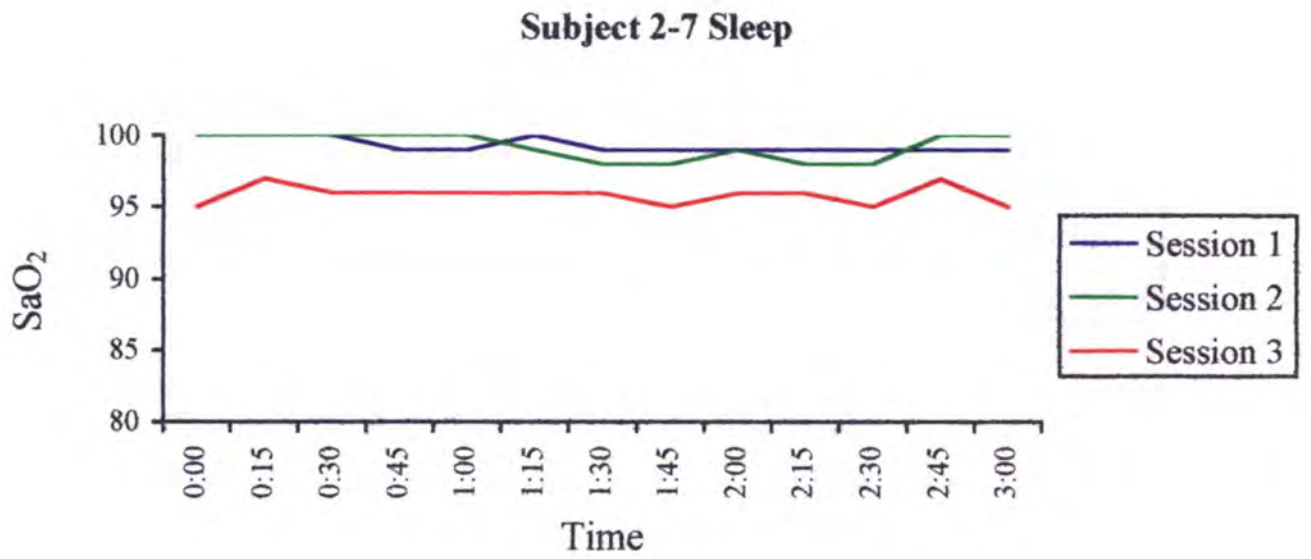
Graph 19. SaO_2 represents oxygen saturation percentage. Time represents minutes:seconds of session.

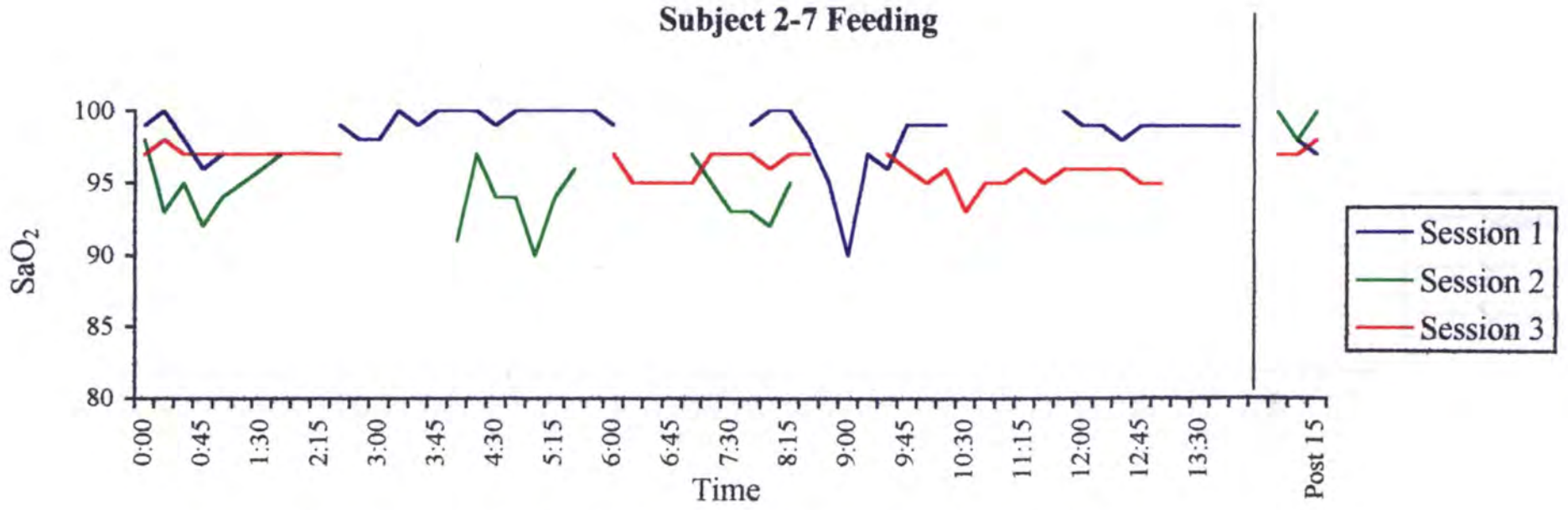
Graph 21



Graph 21. SaO_2 represents oxygen saturation. Time represents minutes:seconds of session.

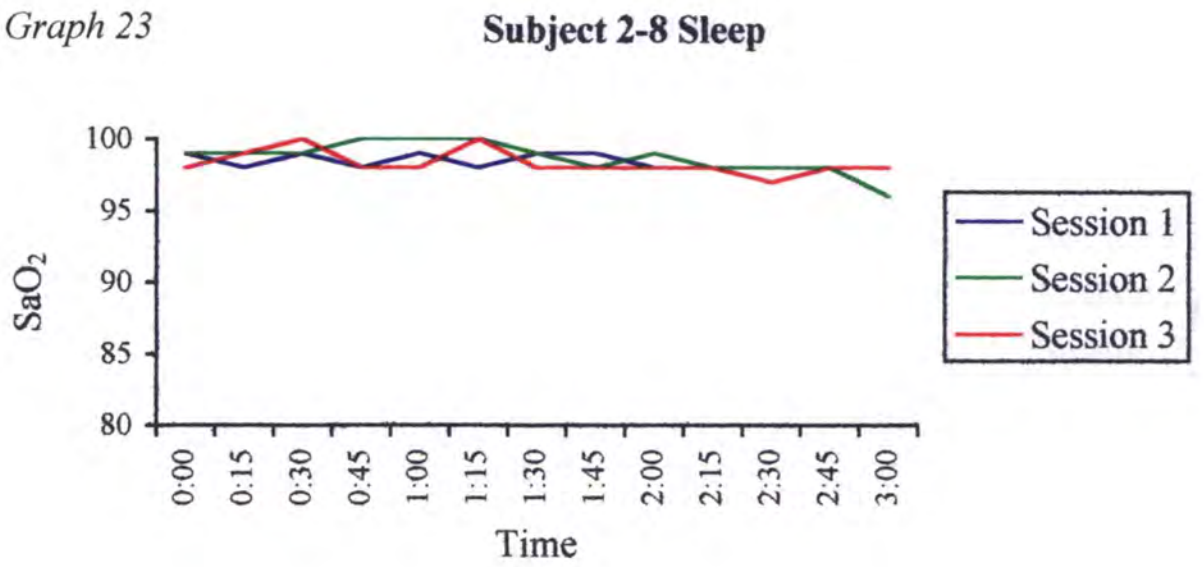
Graph 22

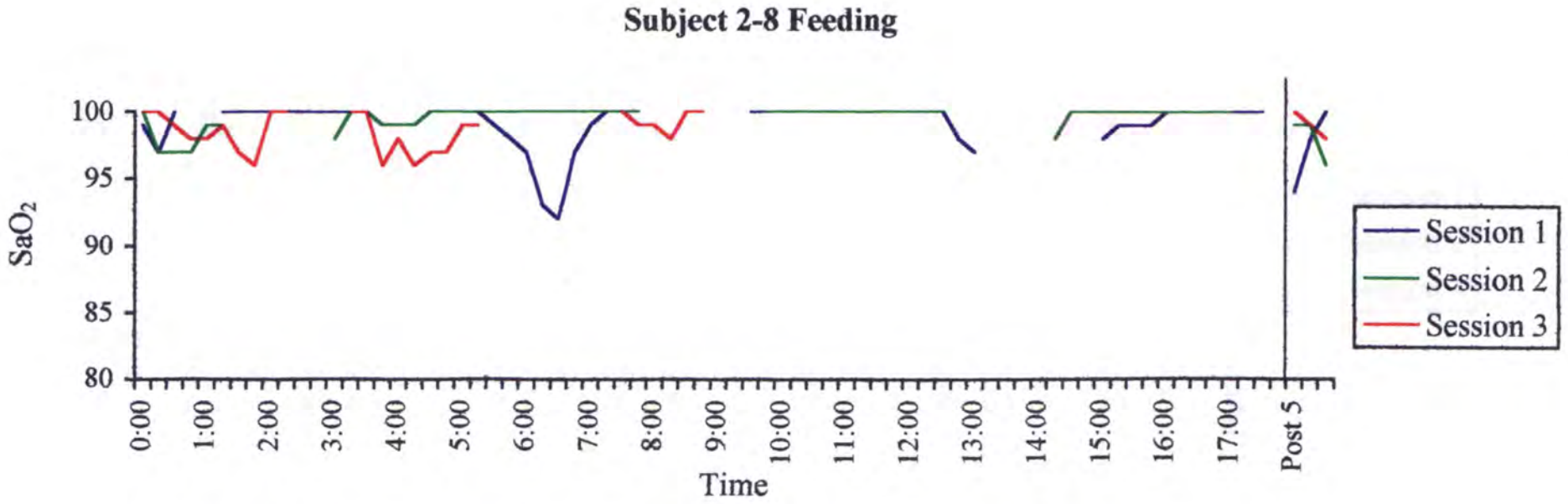




Graph 22. SaO_2 represents oxygen saturation. Time represents minutes:seconds of session.

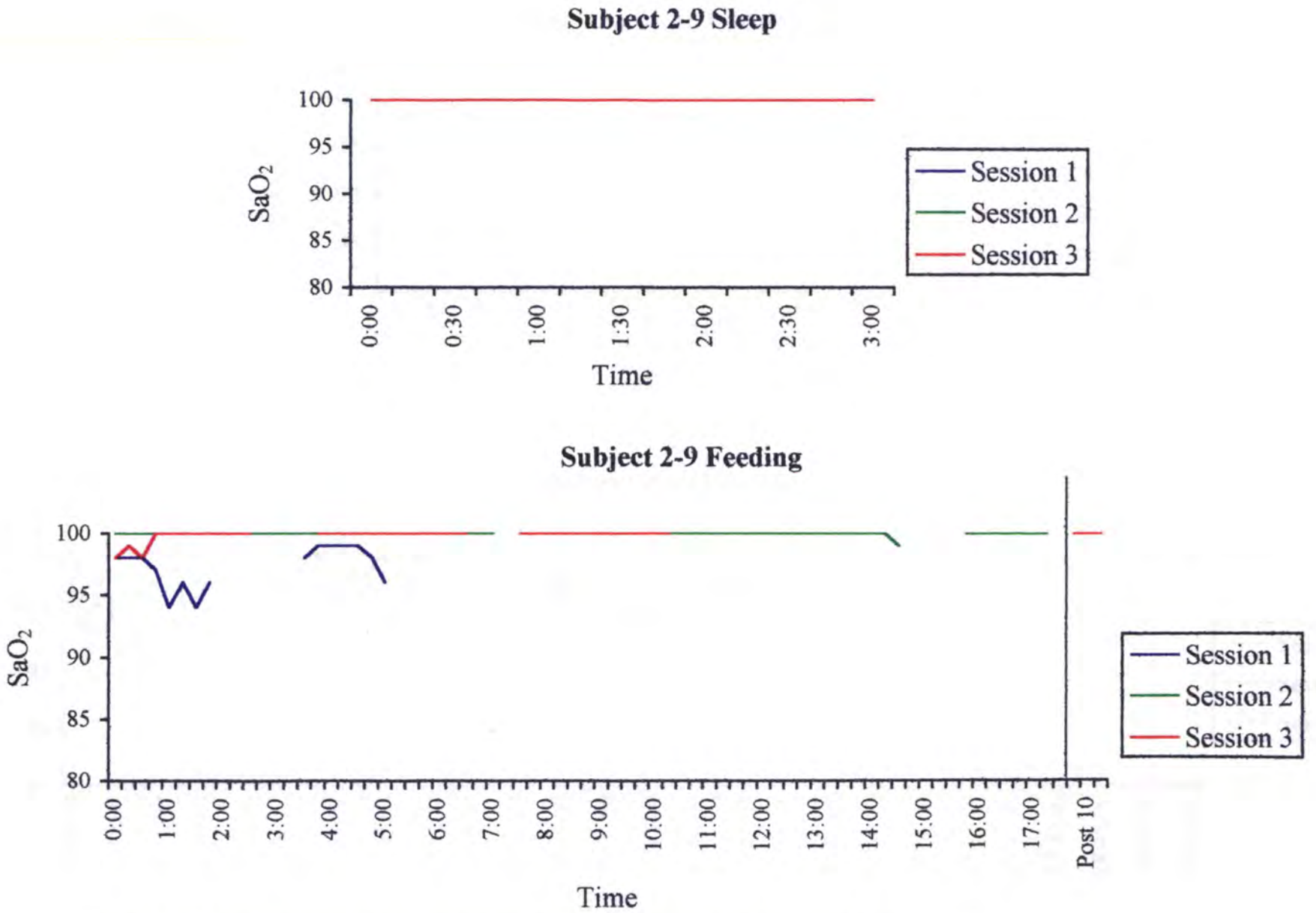
Graph 23





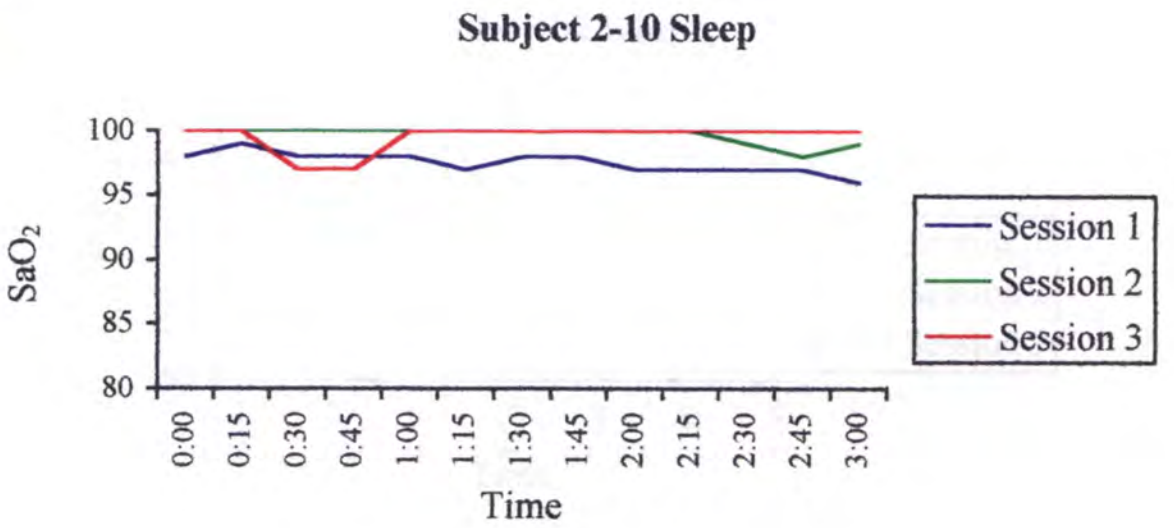
Graph 23. SaO_2 represents oxygen saturation. Time represents minutes:seconds of session.

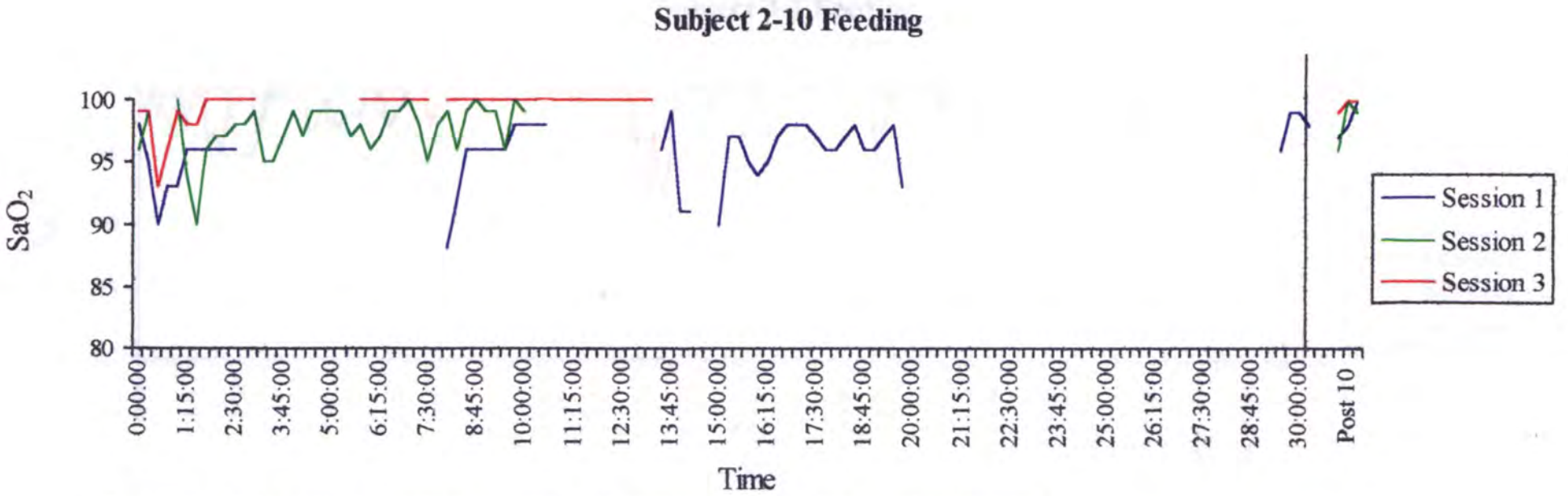
Graph 24



Graph 24. SaO_2 represents oxygen saturation. Time represents minutes:seconds of session.

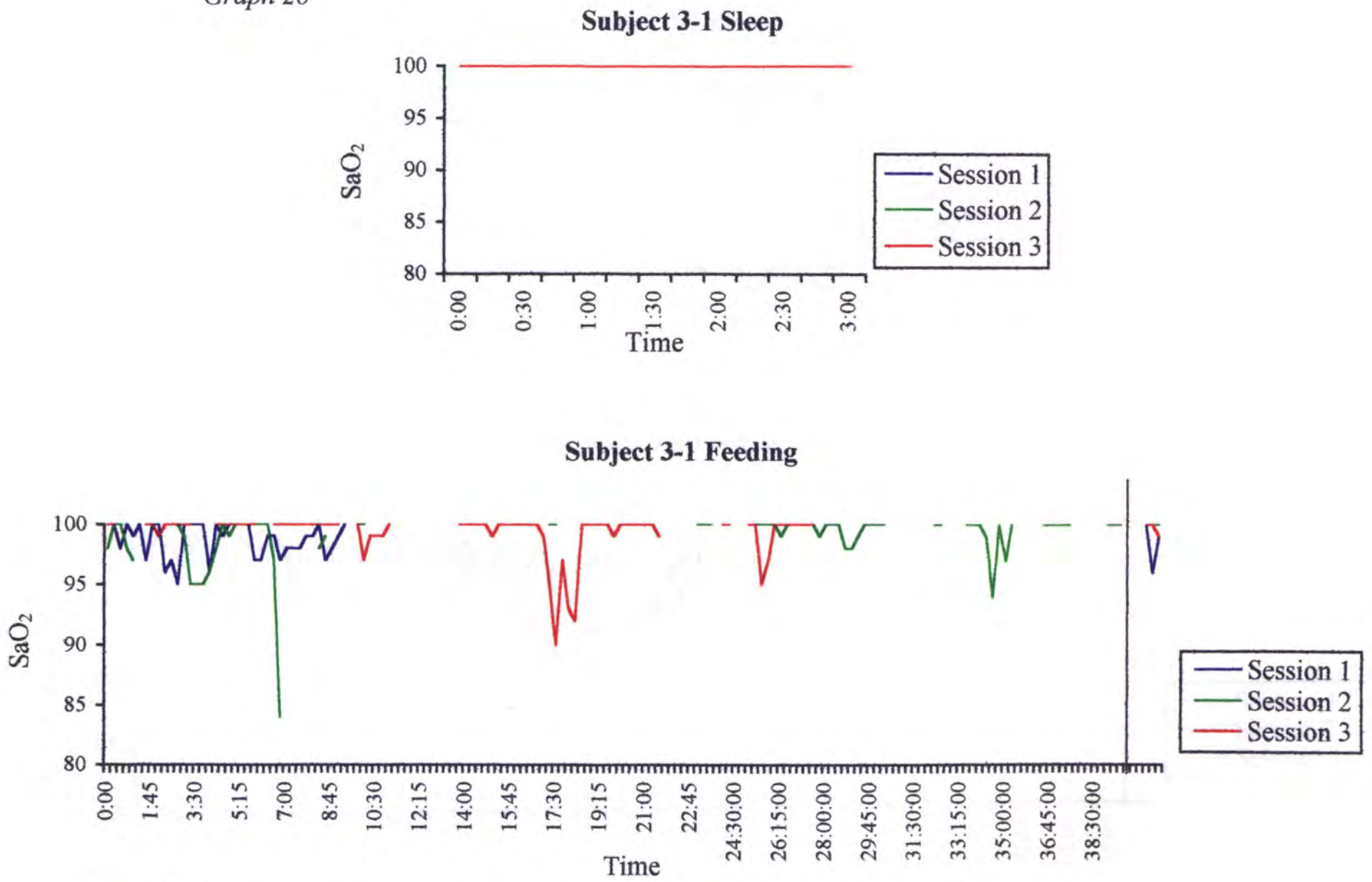
Graph 25





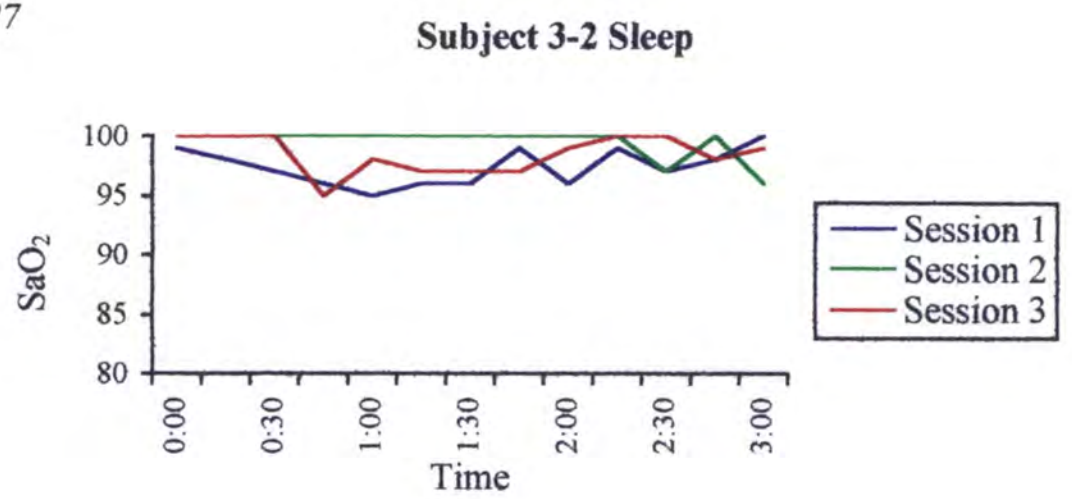
Graph 25. SaO_2 represents oxygen saturation. Time represents minutes:seconds of session.

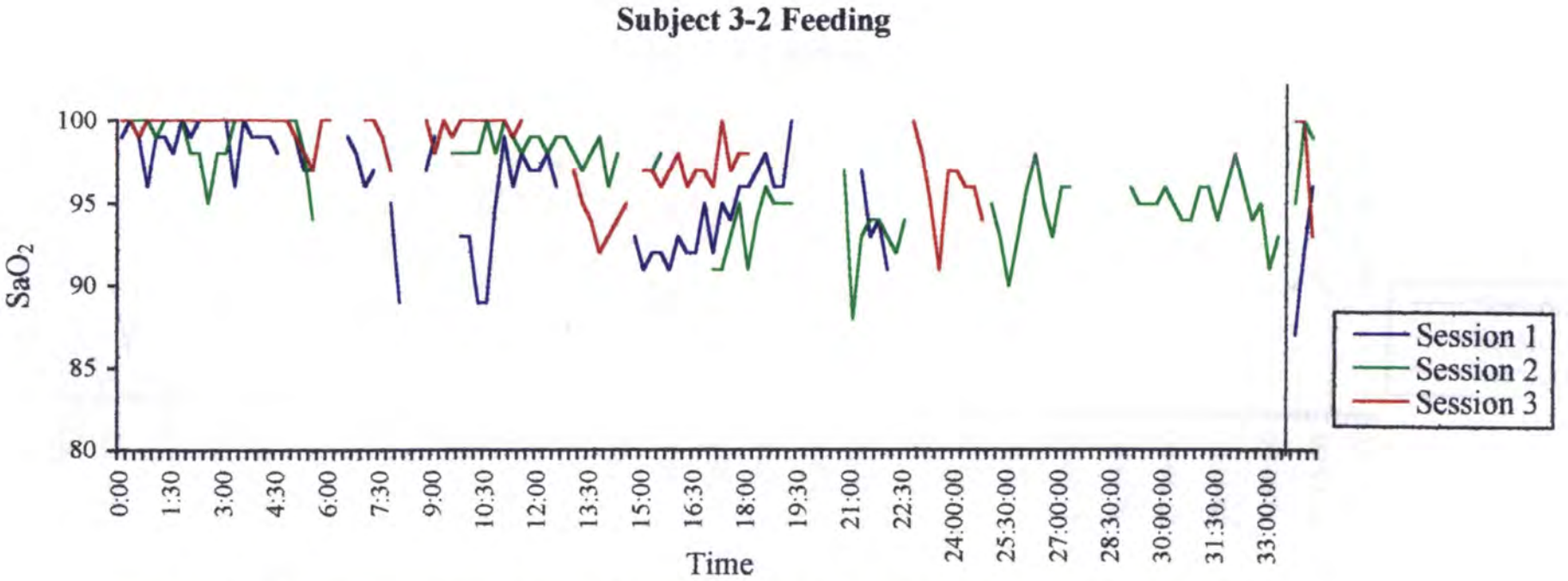
Graph 26



Graph 26. SaO_2 represents oxygen saturation percentage. Time represents minutes:seconds of session.

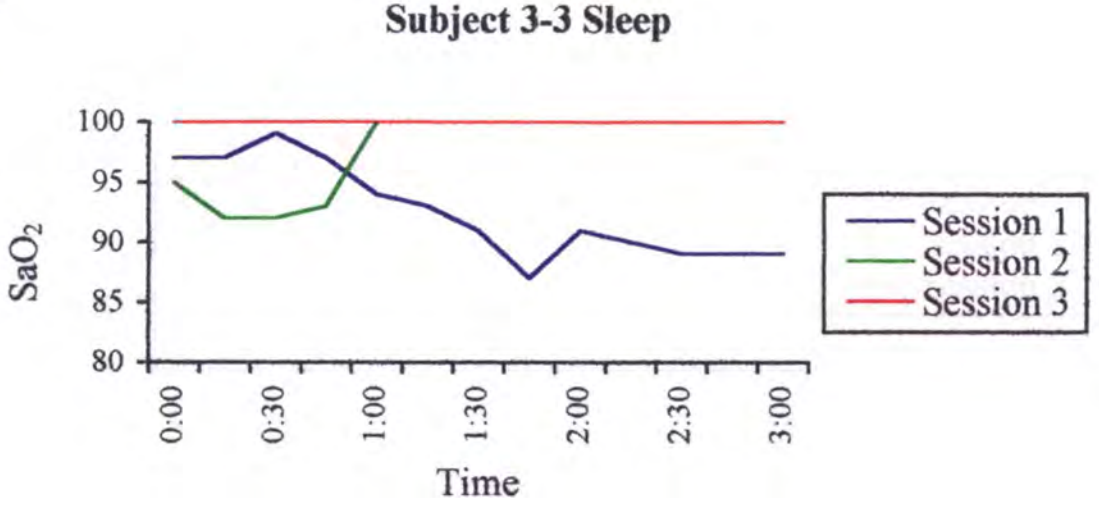
Graph 27

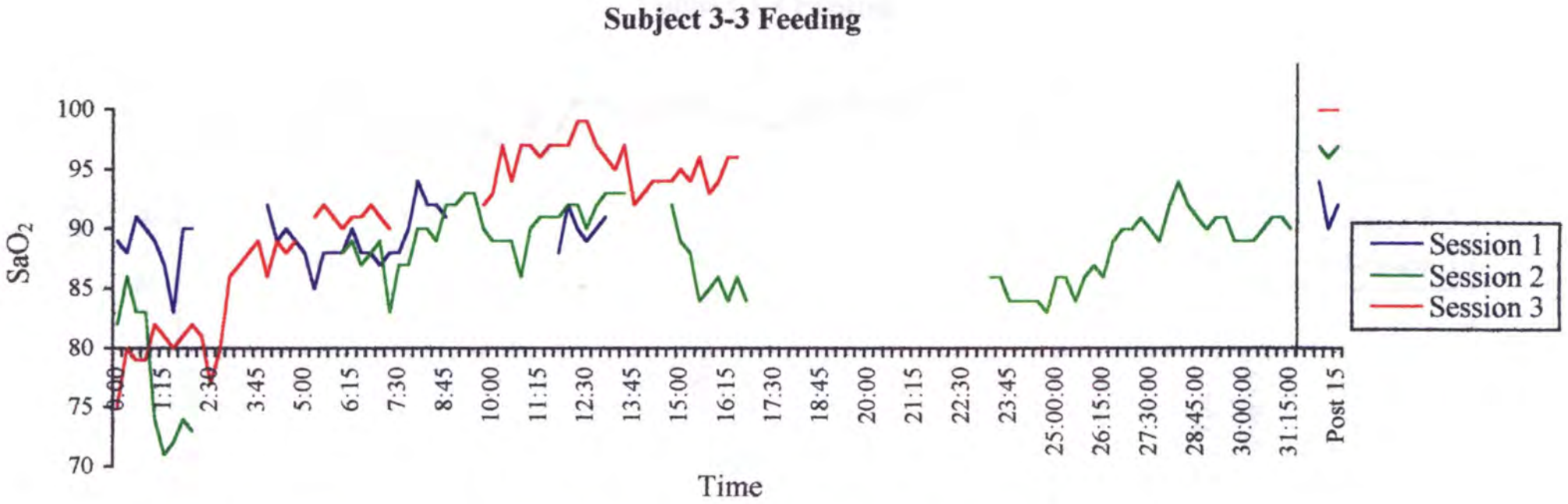




Graph 27. SaO_2 represents oxygen saturation percentage. Time represents minutes:seconds of session.

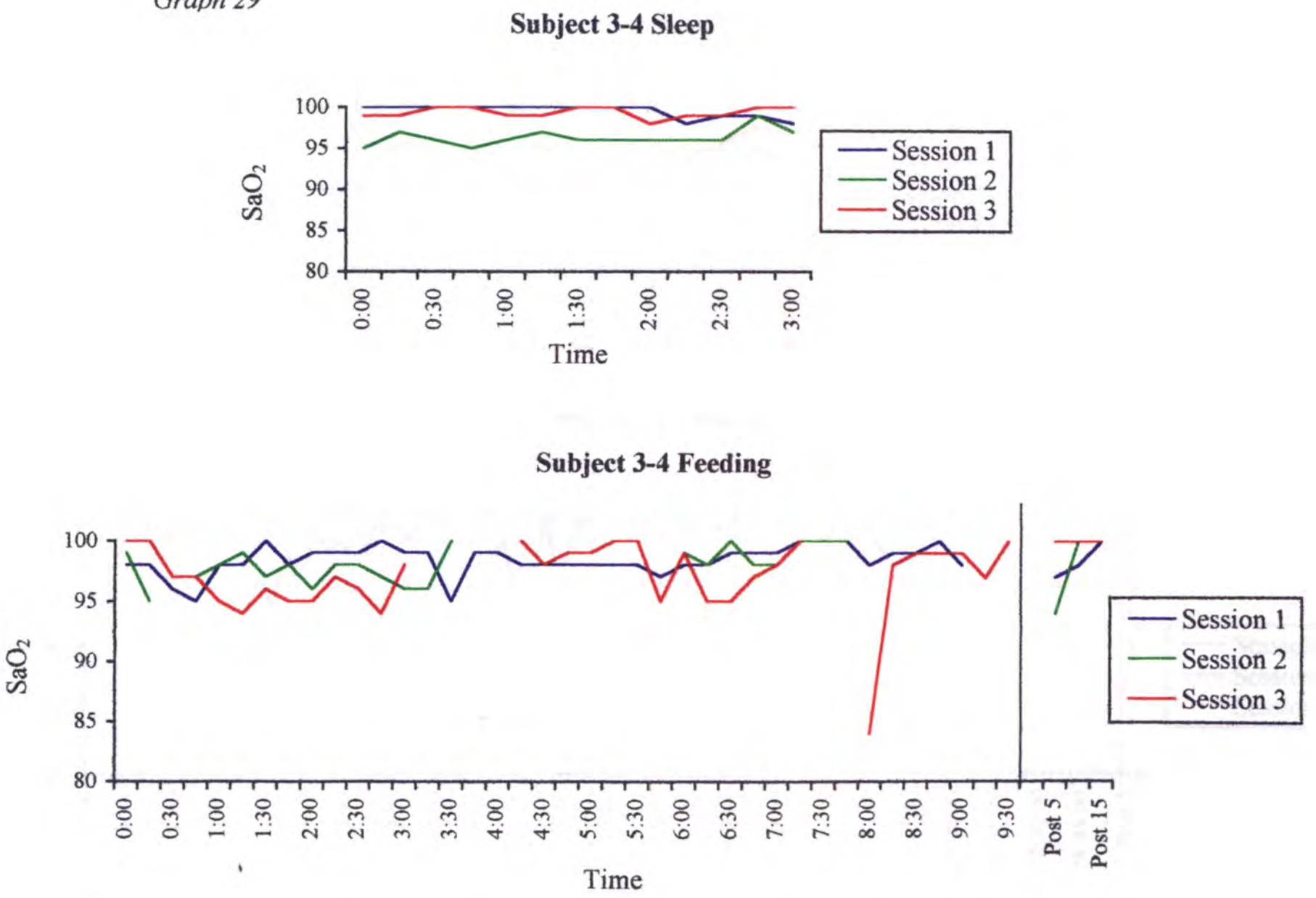
Graph 28





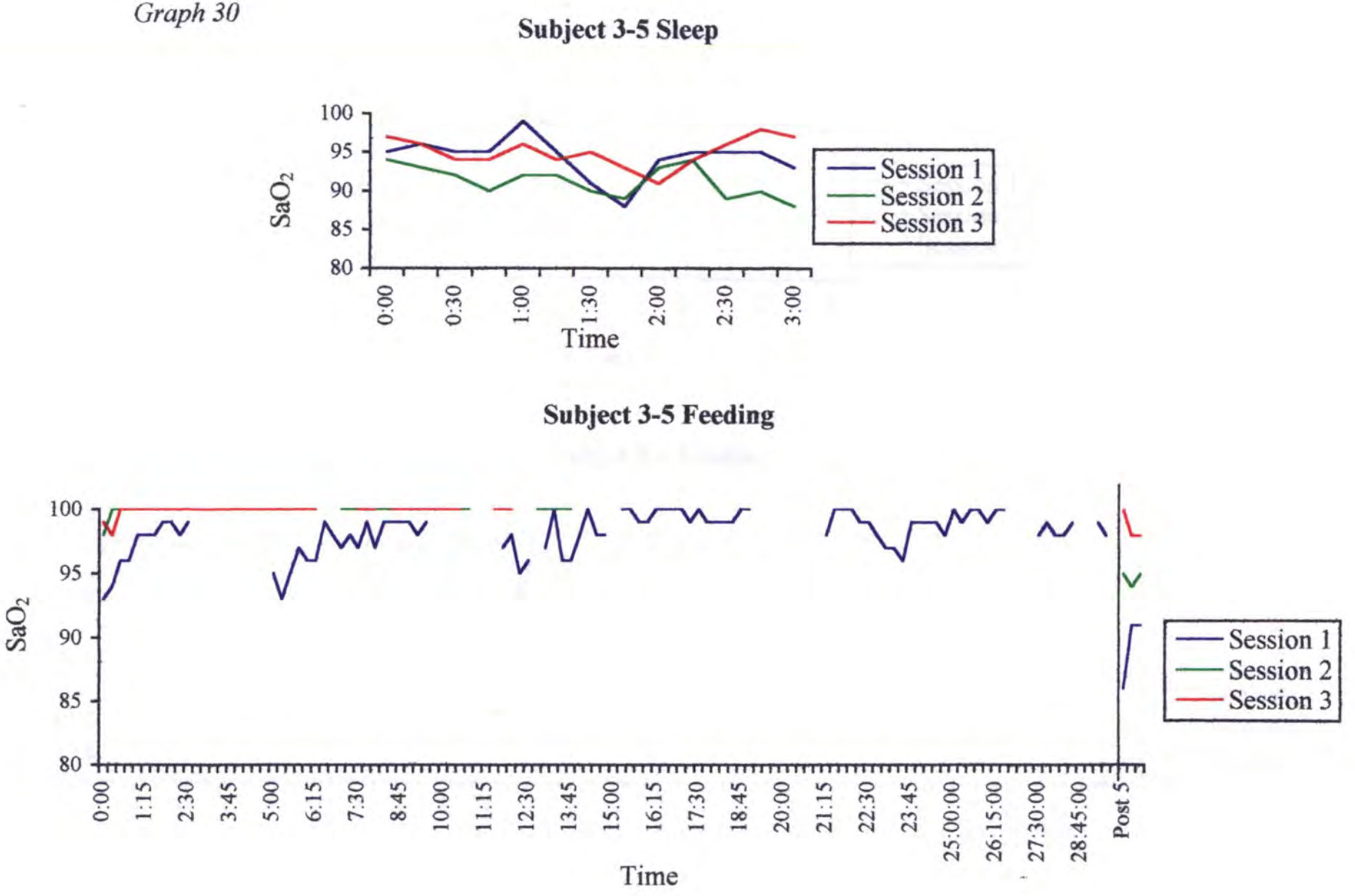
Graph 28. SaO_2 represents oxygen saturation percentage. Time represents minutes:seconds of session.

Graph 29



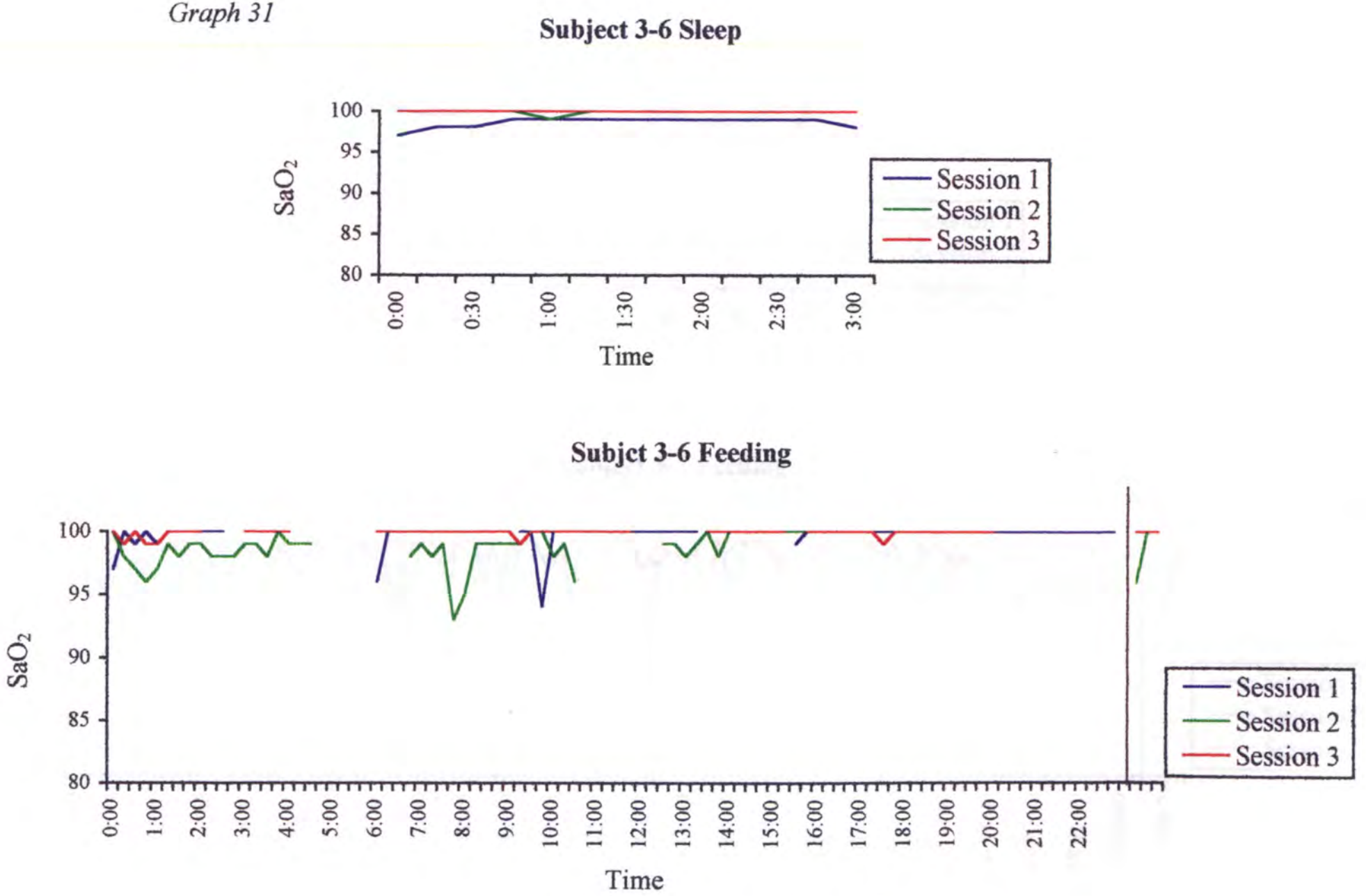
Graph 29. SaO_2 represents oxygen saturation percentage. Time represents minutes:seconds of session.

Graph 30



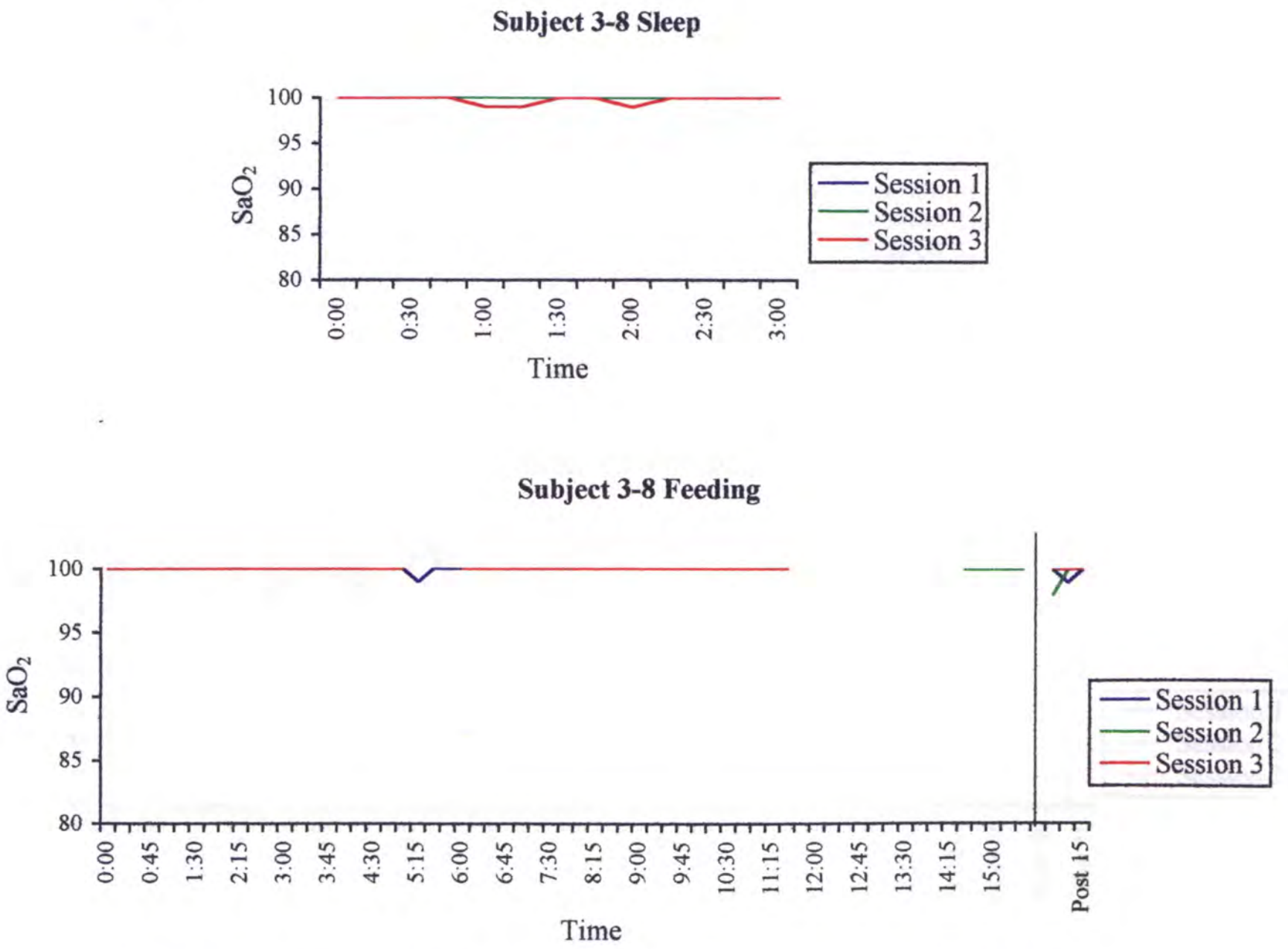
Graph 30. SaO_2 represents oxygen saturation percentage. Time represents minutes:seconds of session.

Graph 31



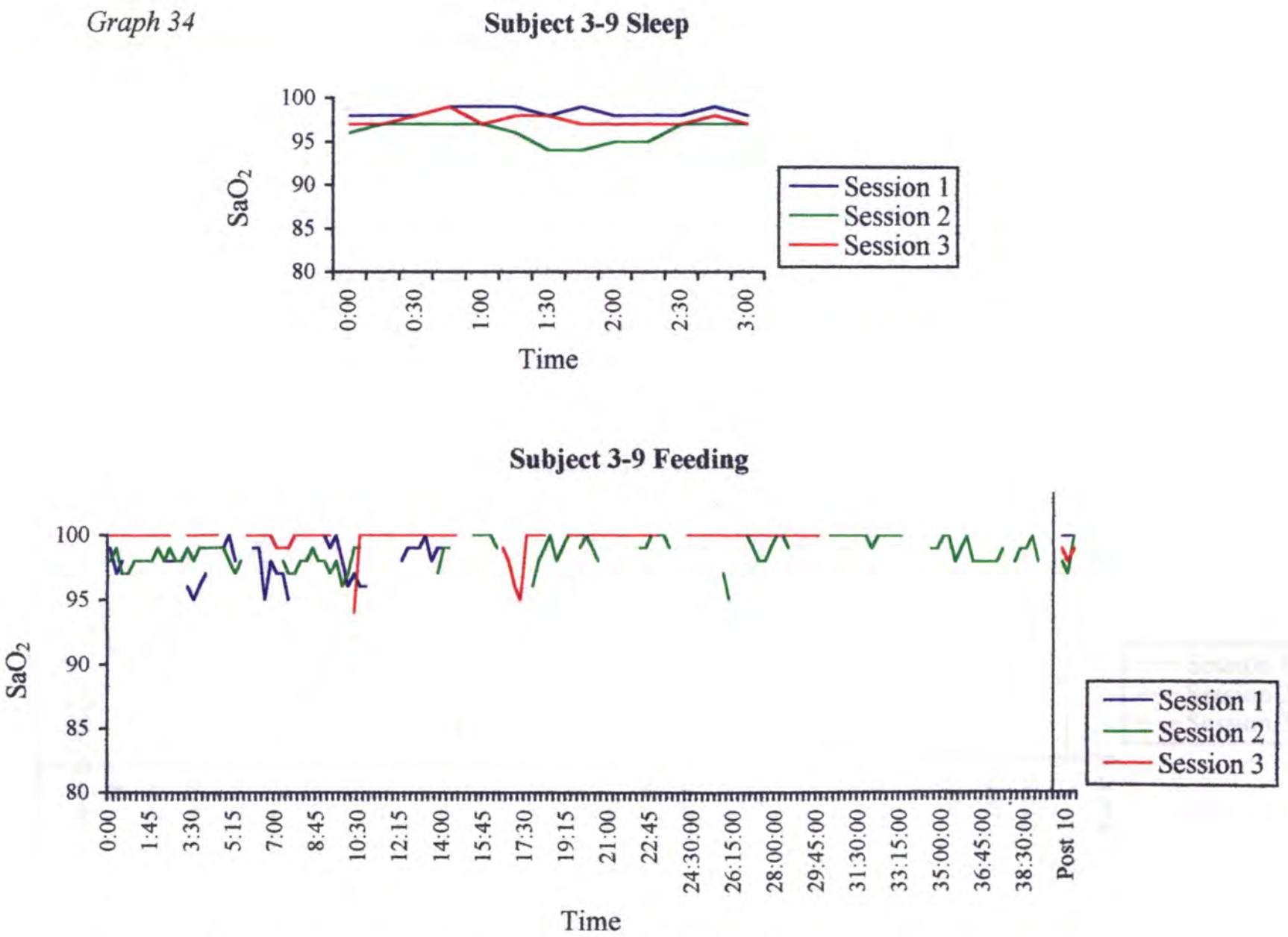
Graph 31. SaO_2 represents oxygen saturation percentage. Time represents minutes:seconds of session.

Graph 33



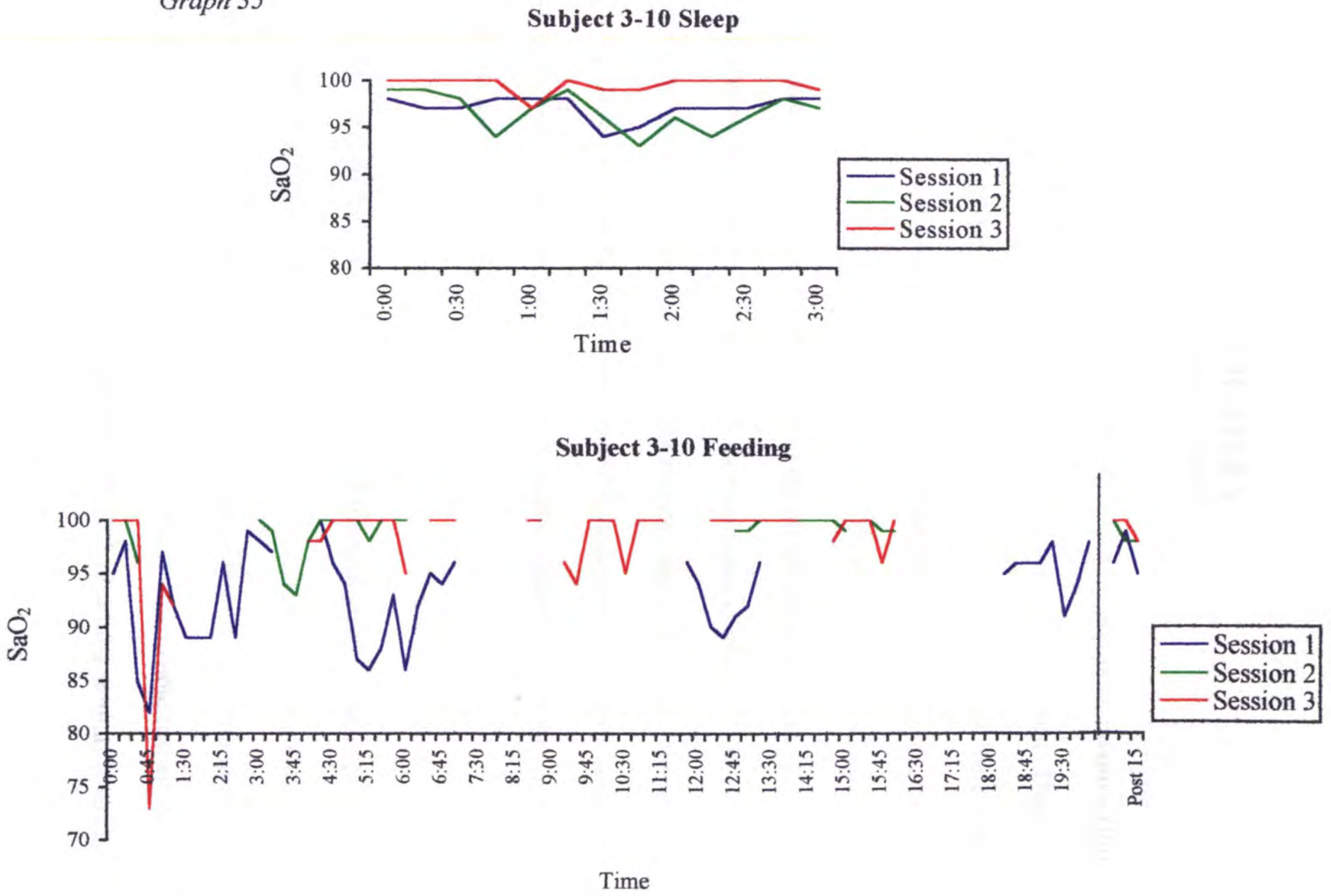
Graph 33. SaO_2 represents oxygen saturation percentage. Time represents minutes:seconds of session.

Graph 34



Graph 34. SaO_2 represents oxygen saturation percentage. Time represents minutes:seconds of session.

Graph 35



Graph 35. SaO_2 represents oxygen saturation percentage. Time represents minutes:seconds of session.

CHAPTER V
DISCUSSION

This study aimed to determine the differences various groups of infants exhibit in regards to changes in SaO_2 experienced during feeding as compared to rest. Data analysis performed for this study confirms the null hypothesis stating that there is no difference in the means of each group. Sample size calculations indicated that ten subjects per group would yield 80% power (alpha=0.05) to detect an effect size of 0.36, where effect size is defined to be the variance of the means divided by the common standard deviation (SD) squared. Variance of the means and common SD were estimated based on expected values. However, upon data analysis, these observed values did not correlate with those anticipated suggesting a possible under-powered study. However, the patterns depicted in graphs 3 and 4 display valuable information for the continuation of study in this area.

Sleep

Graph 1 reveals the mean sleep SaO_2 values for each group. The mean value for Group 3 is lower than that of the other groups (97.830% versus 98.290 for Group 1 and 98.320 for Group 2). This supports the notion that the preterm infants with respiratory issues generally have lower levels of SaO_2. It is also interesting to note that all the infants in this study who were free of respiratory illness had similar saturation levels during sleep regardless of their gestational age at birth.

Feeding

The maximum change in SaO_2 determined by this study incorporates each individual's SaO_2 value with the greatest change during feeding per session. This value is then subtracted from the mean sleep value. Therefore, the SaO_2 values recorded at the beginning of the feeding session (Time 0) are important as they present the initial data from which all else is determined. Relatively large SDs for Groups 1 and 3 represent a large variation among the data collected at the initiation of feeding. However, the mean maximum change during feeding in each group exhibits a sequential decrease in SaO_2 levels as the subjects get younger and more fragile with respiratory illness. Both the values of Time 0 and those representing the maximum change during feeding are revealed in Graph 36.

Graph 36

Feeding SaO_2 Values

Group	Time 0	Maximum Change
1 - Full-term, healthy	97.2%	95.6%
2 - Preterm, healthy	98.1%	94.93%
3 - Preterm, ill	97.3%	92.5%

Graph 36. SaO_2 represents oxygen saturation. Time 0 is the time of bottle presentation.

A pattern is noted in the sequential increase of these values across the three infant groups. Additionally, the mean changes for each group must be related to the initial values of sleep. Group 3 presented the lowest average level of SaO_2 during rest and the greatest amount of change between activities. Therefore, the lowest initial value combined with the largest change creates the lowest level of oxygenation during feeding.

All of these values for sleep averages, maximum change values, and the differences occurring among each group are outlined in chart 37.

Chart 37

Variation of SaO_2 Values

Group	Sleep Average (SD)	Feeding Max Change (SD)	Actual Difference: Sleep - Feeding
1 - Full-term, healthy	98.29% (2.29)	95.6% (4.169)	↓2.7%
2 - Preterm, healthy	98.32% (2.285)	94.93% (2.847)	↓3.39%
3 - Preterm, ill	97.83% (1.989)	92.5% (5.471)	↓5.33%

Graph 37. SaO_2 represents oxygen saturation.

Conclusions

The research presented has demonstrated that the subjects in this study exhibited altered SaO_2 levels varying dependently upon an infant's gestational birth-age and respiratory health status. Though the small sample size possibly restricted the statistical significance of the data results, definite patterns are noted throughout the data analysis.

Preterm infants with respiratory anomalies, in this research, exhibited the most drastic changes in SaO_2 between sleeping and feeding states with an average change of 5.33%. The infants participating in this research, preterm or full-term, without history of respiratory illness revealed similar SaO_2 (2.71% and 3.39%, respectively) with a comparatively less amount of SaO_2 variation.

Recommendations

For future studies, a few alterations to the present study may enhance the statistical significance of the findings. It is recommended that a larger sample size be used in order to decrease the detectable effect size within the results and intensify the

opportunity to establish statistically significant data regarding various infants' oxygenation changes during feeding.

Data collection incorporating specific behavioral changes during sleep and feeding sessions may offer insight to various fluctuations in the oxygenation readings due to the sensitivity of the pulse oximeter. Accounting for the duration and amount of intake during each feeding session would also be recommended to increase the reliability of the results.

Summary

Three groups of infants were studied regarding their SaO_2 levels during the sleep and the changes that occur while feeding. Both the full-term and preterm healthy infant subject groups demonstrated higher levels of SaO_2 in both settings when compared to the preterm infants who have a history of respiratory illness. The degree to which these groups' oxygenation altered during feeding negatively correlates to the infant's gestational age at birth and respiratory health status. All subject groups demonstrated an appropriate oxygenation increase in the subsequent 15 minutes upon completion of the feeding session.

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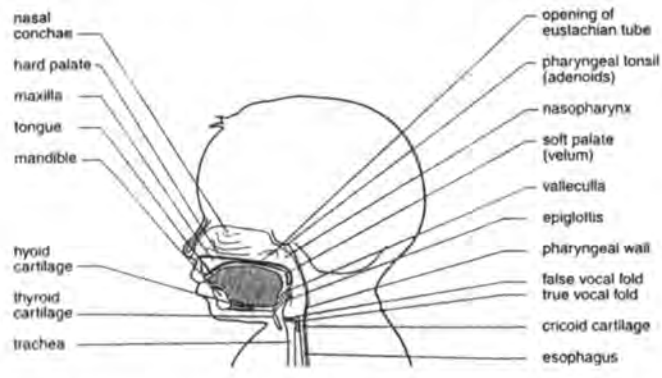
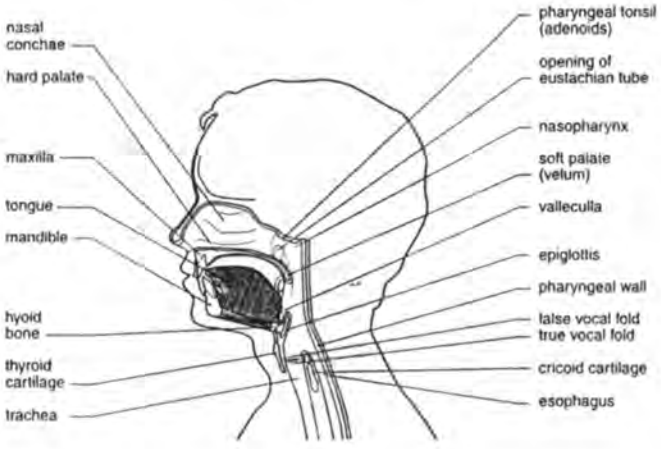
APPENDIX A

INFANT ANATOMY: STRUCTURES FOR RESPIRATION & FEEDING

Anatomical Differences Between the Newborn and the Adult Mouth and Pharynx





1. The intraoral space of the newborn is small.
2. The lower jaw of the newborn is small and slightly retracted.
3. Sucking pads are present in infants but not in adults.
4. The tongue takes up more relative space in mouth of the newborn due to the diminished size of the lower jaw and the presence of sucking pads in the cheeks.
5. The tongue shows restrictions in movement partially because of the restricted intraoral cavity in which it resides.
6. Newborns prefer nasal breathing.
7. The epiglottis and soft palate are in approximation in the newborn as a protective mechanism.
8. The larynx is higher in the neck of the newborn than in the older infant or adult. This reduces the need for sophisticated laryngeal closure to protect the airway during swallowing.
9. The hyoid is formed of cartilage, not bone in the infant.
10. An infant's eustachian tube lies in a horizontal position. It assumes a more vertical angle in the older child and adult.

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APPENDIX B

NEW BALLARD SCORE

Neuromuscular Maturity

	-1	0	1	2	3	4	5
Posture							
Square Window (wrist)	>90°	90°	60°	45°	30°	0°	
Arm Recoil		180°	140°-180°	110°-140°	90-110°	<90°	
Popliteal Angle	180°	160°	140°	120°	100°	90°	<90°
Scarf Sign							
Heel to Ear							

Physical Maturity

Skin	sticky friable transparent	gelatinous red, translucent	smooth pink, visible veins	superficial peeling &/or rash, few veins	cracking pale areas rare veins	parchment deep cracking no vessels	leathery cracked wrinkled
Lanugo	none	sparse	abundant	thinning	bald areas	mostly bald	
Plantar Surface	heel-toe 40-50 mm: -1 <40 mm: -2	>50mm no crease	faint red marks	anterior transverse crease only	creases ant. 2/3	creases over entire sole	
Breast	imperceptible	barely perceptible	flat areola no bud	stippled areola 1-2mm bud	raised areola 3-4mm bud	full areola 5-10mm bud	
Eye/Ear	lids fused loosely:-1 tightly:-2	lids open pinna flat stays folded	sl. curved pinna; soft, slow recoil	well-curved pinna, soft but ready recoil	formed &firm instant recoil	thick cartilage ear stiff	
Genitals male	scrotum flat, smooth	scrotum empty faint rugae	testes in upper canal rare rugae	testes descending few rugae	testes down good rugae	testes pendulous deep rugae	
Genitals female	clitoris prominent labia flat	prominent clitoris small labia minora	prominent clitoris enlarging minora	majora & minora equally prominent	majora large minora small	majora cover clitoris & minora	

Maturity Rating

score	weeks
-10	20
-5	22
0	24
5	26
10	28
15	30
20	32
25	34
30	36
35	38
40	40
45	42
50	44

Ballard, J. L., Koury, J. C., Wedig, K., Wang, L., Eilers-Walsman, B. L., & Lipp, R. (1991). New Ballard Score, expanded include preterm infants. *Journal of Pediatrics, 119:* 418.

APPENDIX C
DATA FORMS
Sleep Data

ID _____

Date ________ Time ________
Type ________

min 1 x	0:15	____
	0:30	____
____	0:45	____
	1:00	____
min 2 x	1:15	____
	1:30	____
____	1:45	____
	2:00	____
min 3 x	2:15	____
	2:30	____
____	2:45	____
	3:00	____

POS avg. ____
session # ____
input to computer ____

Date ________ Time ________
Type ________

min 1 x	0:15	____
	0:30	____
____	0:45	____
	1:00	____
min 2 x	1:15	____
	1:30	____
____	1:45	____
	2:00	____
min 3 x	2:15	____
	2:30	____
____	2:45	____
	3:00	____

POS avg. ____
session # ____
input to computer ____

Date ________ Time ________
Type ________

min 1 x	0:15	____
	0:30	____
____	0:45	____
	1:00	____
min 2 x	1:15	____
	1:30	____
____	1:45	____
	2:00	____
min 3 x	2:15	____
	2:30	____
____	2:45	____
	3:00	____

POS avg. ____
session # ____
input to computer ____

ID: _____
Date: _____
Time: _____

Feeding Data

Session # _____

	0:15	_____		9:15	_____		18:15	_____
min 1	0:30	_____	min 10	9:30	_____	min 19	18:30	_____
_____	0:45	_____	_____	9:45	_____	_____	18:45	_____
	1:00	_____		10:00	_____		19:00	
	1:15	_____		10:15	_____		19:15	_____
min 2	1:30	_____	min 11	10:30	_____	min 20	19:30	_____
_____	1:45	_____	_____	10:45	_____	_____	19:45	_____
	2:00	_____		11:00			20:00	_____
	2:15	_____		11:15	_____		20:15	_____
min 3	2:30	_____	min 12	11:30	_____	min 21	20:30	_____
_____	2:45	_____	_____	11:45	_____	_____	20:45	_____
	3:00	_____		12:00	_____		21:00	_____
	3:15	_____		12:15	_____		21:15	_____
min 4	3:30	_____	min 13	12:30	_____	min 22	21:30:00	_____
_____	3:45	_____	_____	12:45	_____	_____	21:45	_____
	4:00	_____		13:00	_____		22:00	_____
	4:15	_____		13:15	_____		22:15	_____
min 5	4:30	_____	min 14	13:30	_____	min 23	22:30	_____
_____	4:45	_____	_____	13:45	_____	_____	22:45	_____
	5:00	_____		14:00	_____		23:00	_____
	5:15	_____		14:15	_____		23:15	_____
min 6	5:30	_____	min 15	14:30	_____	min 24	23:30	_____
_____	5:45	_____	_____	14:45	_____	_____	23:45	_____
	6:00	_____		15:00	_____		24:00:00	_____
	6:15	_____		15:15	_____		24:15:00	_____
min 7	6:30	_____	min 16	15:30	_____	min 25	24:30:00	_____
_____	6:45	_____	_____	15:45	_____	_____	24:45:00	_____
	7:00	_____		16:00	_____		25:00:00	_____
	7:15	_____		16:15	_____		25:15:00	_____
min 8	7:30	_____	min 17	16:30	_____	min 26	25:30:00	_____
_____	7:45	_____	_____	16:45	_____	_____	25:45:00	_____
	8:00	_____		17:00	_____		26:00:00	_____
	8:15	_____		17:15	_____		26:15:00	_____
min 9	8:30	_____	min 18	17:30	_____	min 27	26:30:00	_____
_____	8:45	_____	_____	17:45	_____	_____	26:45:00	_____
	9:00	_____		18:00	_____		27:00:00	_____

Average desaturation during entire session = _____

Post-Feeding:

5 min ____ **10 min** _____ **15 min** __