# THE ERGODESIGN OF CHILDBIRTH

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## ABSTRACT

**The main aim of this paper is to showcase the symbiotic potency of an integrated Ergonomics and Design Research. The focus is to capture actionable insights for the design and evaluation of an Obstetric Body-Support System for physiologic childbirth. Such a system would be biomechanically efficient for the mother, in addition to improving the tasks of the birth attendants in the management of labour and ensuring the safety and well-being of the mother and her baby. The current medical model adopted for the management of labour and childbirth in hospitals is discussed to highlight current idiosyncratic procedures adopted in childbirth practices of modern obstetrics, and the challenges and opportunities for design improvement. An evidence-based transdisciplinary method is detailed through a case study to demonstrate how ergonomics research is applied to elicit empirical anatomical, physiological, psychological and behavioural knowledge, to inform the designer with evidence and insight for problem framing, new concept visualization, prototyping, and system evaluation in hospital settings. 'Ergodesign', a hybrid paradigm to humanise labour and childbirth, is proposed as a design science to improve current obstetric practices.**

**Keywords: Ergodesign, Evidence-Based Design Childbirth, System Thinking.**

## INTRODUCTION

This paper, which draws on my doctoral research, examines the current hegemonic culture of childbirth, and the application of ergonomics and design to transform the medically dominated system into a more natural one. Childbirth is a social-technical dilemma. Akin to industrial production methods and processes, technology has increasingly been used to change the natural physiologic function of childbirth to one that is almost entirely augmented and managed by science, machinery and chemistry. The scientific management of labour and childbirth has developed in opposition to the aspiration of a growing number of women who seek a more psychological and meaningful experience in pregnancy, labour and childbirth (Waldenstorm, 1996). The ways in which a mother labours, and how a baby is born, is determined by a techno-culture, controlled by the availability of science and technology, and safety management procedures; rather than by the anatomical, physiological and ergonomic advantages that are naturally endowed to childbearing women. Nowadays, women in developing and developed countries are able to make their own choice on the ways they wish to give birth to their babies. The choices that are available to them, however, are limited to a highly medically dominated system of hospital care (Anderson, 2004; Beckett, 2005; Bergeron, 2007; Bewely & Cockburn, 2004; Bryant et al., 2007).

Penny Simkin (1996) argued that a woman's childbearing experience is deeply influenced by the culture of her society. Every sociocultural group has viewed birth as a major life event and a rite of passage reinforced by specific rules, rituals and taboos, designed to ensure the safety of the mother and her baby. This ethnocentric culture has partly, or entirely, been replaced by a more forceful prevailing deterministic medical culture of obstetric sciences that view natural birth as an illness, rather than as a natural physiologic process better left alone for the mother to perform, without artificial intervention.

Simkin (1996) provided three examples to illustrate the different cultural influences of the management

of childbirth around the world: Birth in the Netherlands is perceived as a 'normal' process. A healthy pregnant woman is likely to be encouraged to labour and give birth in her own home, using the most basic foetal and maternity monitoring techniques. She probably will labour safely and give birth in an upright position, with intact perineum or with only minor tears to her birth canal (Limburg & Smulders, 1992). In Mexico, the type of birth experience a mother will have is likely to be determined by economics. In the city a poor woman, without complications, may give birth in a large labour ward on a bed with no pillow. One or two busy trainee nurses and physicians, using the most basic foetal and maternal techniques, will very likely care for her. The mother will most likely be alone, without loved ones present to support her. She is likely to give birth on a narrow bed, in the lithotomy position with an episiotomy. Women in different socioeconomic groups are perceived as having different maternal needs. Poorer women are supposed to be more stoic and capable to give birth naturally. Wealthy women are supposed to be more delicate and less able to give birth naturally.

## ACTIVE MANAGEMENT OF LABOUR

Childbirth in New Zealand, the United Kingdom, the United States, and other developed countries, is likely to follow an "Active Management of Labour" process - a scientific management regime. A healthy pregnant woman in these countries will probably have chosen to labour without pain. She is likely to be assisted with *Pitocin* to artificially increase uterine contractions, painkillers, and other mechanical aids such as a vacuum extractor, forceps, episiotomy or a Caesarean.

In 1970, active management of labour was a relatively new phenomenon, developed at the National Hospital in Dublin, Ireland. The basic beliefs adopted for active management of labour included: the diagnosis of labour based either on painful contraction and complete cervical effacement or rupture of membrane; one hour after admission, progress is assessed and amniotomy performed; cervical dilation must advance by at least one centimetre per hour or oxytocin is started and increased until the mother has five to seven contractions every 15 minutes; maximum labour length is 12 hours; a midwife stays with each woman throughout the labour; the midwives manage labour; senior staff consults; induction is rare; pain medication is available, but discouraged (Midwifery Today E-News 3:16, 18 April 2001).

The World Health Organisation (1985a) asserted that the active management of labour is now the new norm for childbirth. After 40 years of manipulation and experimentation with technologies, drugs and artificial procedures to alter labour and birth, most mothers, midwives and obstetricians no longer know what natural birth really is. This is a serious problem, as the intervention of modern obstetrics that the world has "relied on for so many years doesn't actually work" (Bugg 2011).

The Ergodesign of Childbirth is an attempt – to apply ergonomics and system design thinking - to break the current cycle of interventions in childbirth that most women around the world have to endure.

It is disturbing that while obstetrics is supposed to adhere to an evidence-based medical model, there appears to be no evidence that the active management of labour has been proven to be better than 'un-managed' natural birth. Crowther et al. (1989) reported that 80% of mothers who were administered oxytocin said that labour hurt more, and over half would not want it again. Simkin (1986) found that 76% of the 159 new mothers she surveyed said that oxytocin drips were stressful and 46% said the same of amniotomy. Virginal examinations were rated as stressful by 56%. External electronic foetal monitoring was found to be stressful by 55% of mothers, and 61% rated internal electronic foetal monitoring to be stressful. Further, 64% rated restriction to be stressful and 77% rated restriction to movement in bed stressful. (Midwifery Today E-News 3:16, 18 April 2001).

Campo (2010) added that active management of labour has been conceptualized within a biomedical framework of risk and pathology that the obstetric discipline perceived as best control by experts in hospital where the emotion and psychological process of childbirth, and women's tacit knowledge

is devalued in favour of a professionally managed mass-production system compatible with capitalist culture. Childbirth is now time-managed, like an industrial process. (Rothman, 1982; Martin 1987; Davis-Floyd, 1992; Plante, 2009; reported by Campo, 2010).

Timing childbirth, as is done in active management is a subjective practice to reduce labour time from an upper limit of 36 hours to 12 hours. It is not an evidence-based practice, as these time limits were arbitrarily based on clinical concerns and not on scientific evidence. According to Thornton & Lilford (1994), timed labour and childbirth has never been evaluated by a randomised trial. A recent Cochrane Library study, comparing 1,338 low risk mothers who were given Pitocin to shorten labour, with those with no treatment, reported that shorter labour time did not reduce the number of Caesarean sections or increase the number of unassisted deliveries (The New York Times, July 25, 2011).

## ERGONOMICS AND DESIGN IN CHILDBIRTH

The New Zealand Ergonomics Society (2011) stated that ergonomics, also referred to as human factors or human factors engineering, is the scientific discipline concerned with the fundamental understanding of interactions among humans and other elements of a system. It is also the application of appropriate methods, theory and data to improve human well-being and overall system performance. Ergonomics is derived from the Greek words 'ergon' (meaning work) and 'nomos' (meaning laws) (www.ergonomics.org.nz/).

The International Ergonomics Association defined ergonomics as:

> *the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to the design in order to optimize human well-being and overall system performance. Ergonomists contribute to the design and evaluation of tasks, jobs, products, environments and system in order to make them compatible with the needs, abilities and limitation of people. (Karwowski, 2000, p.11).*

These two definitions imply that ergonomics consists of two significant components:

1. A research science that seeks to understand the behavioural and performance responses of human beings in a system; and
2. An applied art that uses behaviour principles and data to the design and development of a system. (Meister, 2000).

The notion that ergonomics is both an empirical (scientific) and a creative (art and design) tool, is a compelling strength for changing the ways childbirth is currently managed. To change a well-established system, such as the medical system, is a formidable, participatory, evidence-based process. New knowledge and insight to drive innovation in labour and childbirth processes in hospital settings are keys to this change. Henley-Einion (2003) compared the problems facing mothers in modern obstetrics as “an iceberg of difficulties” (p. 182). She argued that if this iceberg is to be melted, an exploration of its structure and form is necessary, and the understanding used to set up measures to redress the situation.

The biggest challenges for innovative ergonomics reform in the current hospital system are through evidence-based design innovation aimed at devising better systems to replace existing ones. Changing the mindset of obstetricians who are trained to objectify patients to protect themselves by avoiding emotional involvement is a formidable task for the ergonomist or the designer. The mechanising of the human body and defining “machine-body” as the proper object of medical treatment in childbirth frees techno-medical obstetricians from any sense of responsibility for the patient’s mind and spirit (Davis-Floyd, 2001). This professional attitude contradicts ergonomics and design philosophies. Both emphasise human-centredness, and mind and spirit are the central frame of design reference in the human-machine-environment system.

Ulla Waldenstorm (1996) maintained that childbirth is a multidimensional experience. She stressed the importance of approaching childbirth from different perspectives, and called for a more holistic approach that takes into account both the physical and the psychological factors in the management of childbirth. The contemporary medical model is heavily influenced by three paradigms of healthcare: the technocratic, humanistic, and holistic models of medicine.

> *The technocratic model stresses the separation of mind and body and considers the body as a machine; the humanistic model emphasises mind-body connection and consider the body as an organism; and the holistic model insists on an integrated approach to body, mind, and spirit and defines the body as an energy field in constant interaction with other energy fields. (Davis-Floyd, 2001, p.5).*

## EVIDENCE-BASED MEDICINE, PRACTICE AND DESIGN

This paper considers all three paradigms, in an evidence-based practice system to create an Ergonomic Obstetric Body Support system for humanistic and holistic childbirth. Evidence-based medicine, evidence-based design, and evidence-based practice are almost synonymous terms. It may be argued that all reliable medical processes are designed, and both design and medical services are delivered to the client or user through evidence-based professional practice. While evidence-based medicine has claimed to be “the conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients, through integrating individual clinical expertise with the best available external clinical evidence from systematic research” (Sackett, 1996, p. 71), there is little evidence to demonstrate that the medical model adopted for the management of childbirth has been the preferred option, as it disregards the humanistic and holistic dimensions.

The American Psychological Association (2006) defined evidence-based practice as "the integration of the best available research with clinical expertise in the context of patient characteristics, culture and preferences" (p. 273). It is an accepted scientific approach to improving the impact of practice in medicine, psychology, social work, nursing and allied fields. Evidence-based practice in medicine puts particular emphasis on the results of experimental comparisons to document the efficacy of treatments against untreated control groups, against other treatments, or both (Saskett et al., 1996). Unfortunately, the active management of childbirth is described to be a “history of unchecked practice” during the past three decades. This is the main reason why interventions with little or no benefit have continued to be used (Lugina et al., 2004).

The challenge facing innovation for childbirth is the adoption of an evidence-based sociotechnical optimization design approach, whereby advanced technologies are harnessed to ensure that the safety and experience of mothers in childbirth is optimized. Rather than allowing the multidimensional process of childbirth to be subsumed and shackled in the obstetrics/medical discipline, we need to rethink, reframe and redesign the active management of labour. We must embrace its complexity and importance, with the view to transforming the whole process via a transdisciplinary design approach that interacts with art, science and technology to enable innovation to take place. Sociocultural, emotional, and experiential dimensions do not bode well with modern obstetrics.  Nor can religious, political and ethical complexities of childbirth be resolved by the current medical model for the care of mothers and babies in hospitals.

Designers as change agents can significantly improve the management of labour and childbirth in hospital settings. To achieve this, designers must adopt an empirical, participatory and evidence-based research approach, in order to gain support and credibility with professionals who are weaned under the medical model of practice. Lawrence (1998), writing on evidence-based dentistry, suggested five important steps for evidence-based practice that is relevant to designing for patient care:

1. Ask evidence-based questions (problem identification and framing);
2. Search for current best evidence;

3. Critically appraise information;
4. Apply information to inform design (e.g. the area of diagnosis, prognosis, treatment, potential harm); and
5. Evaluate design outcomes.

While this process may be deemed rigorous enough for evidence-based dentistry practice, designing for childbirth is significantly more complex. The management and care of the mother and the baby during childbirth requires a wide range of skills and knowledge from different disciplines. Extensive medical, technological and scientific knowledge are deemed necessary to ensure that the safety and well-being of human life in maternity hospitals are guaranteed. A caregiver must combine technical knowhow with compassion and sensitivity for the selection of medicine and technology according to individual symptoms and needs – a combination of art, science and know-how.

Not unlike normal production and manufacturing processes, as we have seen, new technology, legal values, and social changes are affecting medicine in general, and obstetrics in particular, with profound uncertainty, fear and controversy. Much of this problem is centred on the invasive procedure in modern obstetrics, such as the timed-labour, drugs and mechanical interferences with the normal process of childbirth. So much so, that obstetrics has now become one of the areas of medicine most opened to public and media scrutiny.

## ERGONOMICS APPROACH: HUMAN-MACHINE-ENVIRONMENT SYSTEM

Like most complex occupational tasks, the problems affecting childbirth could be most appropriately studied within the confines of the human-machine environment system, or the Ergonomics Approach. The application of ergonomics in obstetrics allows the human-machine, and the human-environmental interface problems, involving psychological, physiological and biomechanical factors, to be analysed, optimized, designed and evaluated more scientifically, according to evidence-based principles. However, it must be mentioned that the implementation of design in obstetrics and childbirth is, by far, more difficult than any industrial processes, because childbirth is a critical and highly complex physiological process involving the safety and well-being of both mother and baby. This is a new frontier that few, if any, ergonomists or designers have ventured into before. Consequently, there is an acute shortage of ergonomics data, including basic anthropometric, dimensional, anatomical and biomechanical aspects that the designer could apply readily. As labour and childbirth have always been entirely private affairs, the generation of data, research protocol, ethics, system design and evaluation methods have presented challenges, seldom found in industrial settings. These issues have necessitated a more sophisticated/multifaceted trandisciplinary methodology to address the problems alluded to above.

Transdisciplinary studies are projects that integrate academic research from unrelated disciplines and non-academic participants, such as ergonomists, designers, obstetricians and the public (mothers), to research a common goal, create new knowledge and theory, and to design a new system or service. Transdisciplinary methods combine interdisciplinary methods with a participatory approach (Tress et al., 2008). The need for disciplinary connection or integrated research in childbirth is motivated by the fact that the complexity of modern obstetrics problems, such as labour and childbirth, in the rapidly changing technological world is difficult to be resolved in any single way or by any single discipline.

According to Miller et al. (2008), epistemological connections or pluralism such as in multidisciplinary, interdisciplinary, and transdisciplinary research, and application, contribute four important elements to research enquiries:

1. It acknowledges the validity and value of multiple ways of knowing;
2. It asserts that integrating these epistemologies results in a more complete understand of complex issues, such as the management of childbirth;
3. It accepts that the inclusion of different disciplines would require cross fertilisation

that would benefit research and design outcomes, and

4. It requires that disciplinary researchers work together to find ways to benefit from each other's approaches rather than compromise them.

The key to successful transdisciplinary design is the ability to identify and frame evidence-based problems and opportunities from clinical evidence, transforming them into actionable insights to inform design innovation. Both ergonomics and design know-how and practices are needed to transform key evidence, knowledge and theory into tangible product, service, and system that are functional, usable and desirable for mothers, midwives, obstetricians and other clinicians involved in the management of childbirth.

## ERGODESIGN

A paradigm shift in the way designers do research and practice design in complex systems, such as the management of childbirth, is long overdue. The answer lies in the creative harmonising and fusion of ergonomics and design to coerce a more compatible and integrated approach for ergonomics theory and design application to coexist iteratively and seamlessly.

This is the concept of Ergodesign. Applying ergonomics and design as separate disciplines militates cohesive design thinking and the creative processes. Besides, the symbiotic aspects of Ergodesign, the truly interdisciplinary attributes become an effective and synergistic design tool that is significantly more powerful and effective than conventional approaches of applying ergonomics and design as separate disciplines. The Ergodesigner, as a scientist and designer, as well as a change-agent, plays a vital role in problem solving, designing and ensuring that the function, usability and safety of intricate human-equipment-environmental systems are well researched and developed.

### *ERGODESIGN AS A HYBRID PARADIGM*

Ergodesign, bioengineering, mechatronics, sociotechnical systems and so on, are comparatively current notions of the need for integration and interlinkages between disciplines to enable the study, understanding and constructing of new knowledge in a society that is changing both in speed and complexity. This enables a discipline, or field, to form smart clusters to produce new knowledge, solve problems, improve efficiency, and ensure that innovation can be harnessed more reliably, viably and creatively. The aim is to capture new insights via the integration and application of the duality and synergistic perspectives of interdisciplinary knowledge.

A decade or two ago it was comparatively easy to explain the function of a telephone to a human factor engineer, even though the mechanism and voice transfer were complex. In recent times, it is getting significantly more difficult, if not impossible to do so, as the design of the telephone such as the Apple iPhone not only involves mechanics and optics, but also electronics and software. The convergence of functions of such products and processes has necessitated a synergistic integration of technical, conceptual and behavioural know-how – to enable meaningful sociotechnical optimization to take place. The design and development of successful and innovative products is becoming increasingly more complex and pluralistic – often requiring more than the knowledge and know-how of a single discipline. Hence, the potency and elegance of Ergodesign.

Despite the progress of interdisciplinary research, much difficulty still exists. Miller et al (2008) cautioned scholars, educators, and practitioners to be vigilant of the ways in which interdisciplinary research are conducted. Epistemological pluralism, as an integrated approach for conducting collaborative research and practice, recognises valuable ways of knowing that are specific in different disciplines. For example, in terms of Ergodesign, 'ergonomics' may be considered an empirical discipline for generating new knowledge on the capabilities and limitation of the human operator via positivism; whereas 'design' is an interpretive or heuristic discipline for the design of products, services or systems using ideation, visualization, prototyping creative skills via artistic interpretation and construction of meaning and experience innovation.

While the benefits of making intimate connection across disciplines, such as in ergonomics and design that are enshrined in Ergodesign, are increasingly becoming indispensible, many joint efforts are hindered by disciplinary problems, including a tendency to privilege a single epistemology and disciplinary perspective of the researcher (Rescher 2003); instead of cultivating an open mindset to take advantage of the different epistemologies, or theory of knowledge that each discipline brings to bear in knowledge creation, articulation and application. These are exactly the reasons, as discussed later, why Ergodesign has been proposed to create new knowledge and practice design more efficiently, interactively and seamlessly.

Ergodesign is a hybrid paradigm. It embraces a mixed quantitative and qualitative research method for the production of new knowledge and tangible design. This merging of the science-design disciplines is essential for addressing increasing complex societal and technological issues. Friedman (2003) posited that technology and design affects us profoundly. Our daily life is surrounded by, and influenced by a vast range of technology that mediates most of how we work, live and play. As the man-made world is increasingly replacing the natural world by the progressive introduction of technology and artefacts that alter our environment, ergonomics and design now plays a role in the general evolution of the environment, and the design process takes on new meaning. Consequently, new technologies and their successful implementation through design and innovation, have evolutionised the way we view design, from simple craft tradition to increasingly more complex products, infrastructures and systems, and other commercially, industrially and environmentally-altering artefacts (Friedman, 2003).

The complex design problems that designers have to solve have led to the evolution and development of blended or mixed modes of research inquiries and design practices. Hybrid technology, that is increasingly being harnessed for designing say, mechanical and electronic hybrid cars for example, has necessitated the need for hybrid; pluralistic and synergistic design methodology such as Ergodesign. The challenges facing designers to solve problems in the complex world can no longer be subsumed in the current model of design practice that is supported by a heuristic paradigm for craft production. Current design problems and opportunities has necessitated researchers and designers to shift current design thinking and conceptualizing in product, system and service designs, not only to a preferred one, but one that would change the cultural perception of how designers harness, use and transform advanced technologies in the future.

Within contemporary institutional, industry and business designs, explicit research information to support design propositions is increasingly being demanded to align left-brain rationality with right brain creativity. This requirement and expectation of the designer has led to the merging of human factors, brand strategy, business model and product envisioning in ‘Design Thinking’ approaches in design consultancies. Creativity in the design processes must be deliberated within the confines of rationality of the design transformation: the mental function that connects both the rational and the creative minds, in a hybrid, symbiosis, and reflective and iterative manner – such as the Hybrid Paradigm embraced in Ergodesign would provide.

Ergodesign positions design as a hybrid research and practice, not only to design and address complex problems, but as an empirical paradigm capable of knowledge and theory production. Ergodesign is positioned as a new positivist-constructivist paradigm. Instead of perpetuating design as a craft subject, Ergodesign, which is imbued with the potentials to develop new knowledge on the one hand, and practicing design on the other, transforms the traditional craft subject into a design paradigm.

## DESIGN AND RESEARCH PARADIGMS

A paradigm is the theoretical framework of a discipline, which influences the way knowledge is studied and interpreted. The choice of a paradigm sets down the intent, motivation and expectation for the research. For this reason, Ergodesign can be described as a design approach targeted towards studying the human user or operator, to design and develop usable, functional, safe and desirable

systems by the application of evidence-based research and design processes.

Mackenzie and Knipe (2006) maintained that without choosing a paradigm, as the first step in research, there is no basis for subsequent choices regarding methodology, methods, literature or research design. Interestingly, they claimed that "mixed method", such as Ergodesign, "could be used with any paradigm" (npn). They classed the four paradigms as: positivist, constructive/interpretive, transformative and pragmatic. The pragmatic paradigm places the research problem as the central frame of reference for research, and data collection and analysis are chosen to generate knowledge and insights into the question with no philosophical loyalty to any alternative paradigm (Mackenzie, 2006).

Ergodesign, as a hybrid paradigm sits well in this pragmatic paradigm classification. The pragmatic paradigm provides an opportunity to undertake research and design with multiple methods, different worldview, and different assumption as well as different forms of data collected and analysis in the mixed methods (Mackenzie, 2006), that is most useful and suitable for the Ergodesigner. As an interpretive and constructivist researcher, the Ergodesigner tends to focus the research on the human participant's perspective of the situation being studied. Designers as constructivist researchers do not normally begin to construct an idea with theory. They generate or inductively and abductively develop a theory/model or pattern of meanings throughout the iterative design process, often impacting the research with their own culture, background and experience. Both research and design processes adopt iterative and cyclical approaches rather than linear ones (Creswell, 2003, cited in Mackenzie, 2006).

## ERGODESIGN OF CHILDBIRTH

The basic philosophy of ergonomics, in terms of biomechanics, considers the human being to be an organism subject to different sets of laws: the laws of Newtonian mechanics, and the biological laws of life. The philosophy highlights the importance that human activities are surrounded by the physical environment; and inside the human body, the "internal biomechanical environment" or the musculoskeletal system, which responds to the demands of the activity (Tichaure, 1978).

### *ERGONOMIC POSITION FOR CHILDBIRTH*

The position adopted by the mother during labour is considered to be the most important factor for the safe passage of the foetus through the birth cannel. There is biblical and historical evidence that the natural posture adopted by woman during childbirth has always been in some form of the upright position – sitting, squatting, kneeling and standing. The supine position for delivery, adopted in modern hospital, facilitates the management of labour, but it has no established benefit for the maternal mother and the foetus. Many physiological disadvantages that adversely affect maternal well-being and foetal oxygenation are associated with the supine position. (Andrwes & Chrzanowski, 1990; Liu, 1988; Lugina et al., 2004).

The body position or posture is an important criterion for all biomechanical functions and the design of equipment, workspaces and work procedures. It affects the worker's ability to use equipment, reach, hold, push or pull, and it influences the length of time an activity can be performed without adverse health effects such as fatigue and cumulative disorders and disease. Where an activity or posture is assumed to satisfy only the technical requirement, engineering criteria or other constraints, functional inefficiency, fatigue and disease may arise. In order to improve the situation, criteria for designing work activities (labour is hard work!) and the resulting posture must be based on the body's requirements as a living organism (Corlett, 1983). In this context, the relationship between postures, physiology and biomechanics promises tremendous scope for the study, analysis and equipment design for childbirth. Labour is a physiological process. Its efficiency is dependent on good postures, and how the equipment is designed to encourage and support the mother in the most optimum position.

The increasing sophistication of biomechanical analysis and instrumentation in posture analyses has

contributed greatly to this research. Much of the existing work, however, has concentrated on work-related aspects of postures. The major areas of research have been work physiology, manual material handling and the effect on prolonged sitting. The main aims of most of these studies have been for the prevention of lower back injuries and other musculoskeletal diseases, safety and efficiency (Bendix et al., 1976; Corlett & Bishop, 1976; Graudjean et al., 1983; Karhu et al., 1977; Mandal, 1981).

Some postural aspects of childbirth have also been investigated as far back as the 1980s. For example, Jorden (1980) investigated the birthing postures in relationship to the anthropological aspects of four different cultures, and Engleman (1982) studied extensively the birthing postures of primitive people around the world.

The physiological aspects of a variety of birth positions have also been studied by a large number of obstetricians and clinicians. These investigations have been predominantly concerned with the efficiency of labour, drugs requirements, and loss of maternal blood. They were mainly medical and clinical studies (Atwood, 1976; Balaskas, 1985; Caldeyro-Barcia, 1979; Dunn, 1976; Grupta et al., 1987; Howard, 1958; Liu, 1974; Odent, 1985).

Collectively, the problems surrounding childbirth have been extensively investigated by a multitude of disciplines over many hundreds of years. However, no other studies have been found in the literature that examine the subject in a truly integrated or transdisciplinary approach. There were also no studies found which addressed childbirth in an ergonomics and design approach. Furthermore, in nearly all of the studies, no evidence has been found where the functionality, usability and desirability of the equipment were considered to be important for the mother, midwife, obstetrician and clinician.

### *ADVERSE EFFECTS OF THE SUPINE POSITION IN CHILDBIRTH*

The upright position was used in antiquity through the Middle Ages, and until the mid-18$^{th}$ century when Francois Mauriceau who was the obstetrician to the Queen of France replaced the sitting position on the birth stool to the recumbent position in bed to facilitate the management of labour, examinations and the use of the Chamberlen forceps (Caldeyro-Barcia, 1979; Howard, 1958). The recumbent position continued as the posture for labour and delivery during the 19$^{th}$ and early 20$^{th}$ centuries when most births were taking place in the home. By 1979, around 95% of all women in developed countries had hospital deliveries. As hospital births increased, the delivery table replaced the bed, and the woman lay on her back in the lithotomy position.

Throughout the past 50 years, in the study and investigation of the well-being of the mother and her baby, the horizontal position - recumbent, supine or lithotomy - has been regarded to be unnatural and unphysiologic for labour and childbirth (Andrews & Chrzanowski, 1990; Bond, 1973; Caldeyro-Barcia, 1979; Dunn, 1976; Harward, 1958; Liu, 1988; Lugina et al., 2004; Russel, 1969). Gupta et al (1987) and Scott and Kerr (1963) asserted that in the supine position, the weight of the gravid uterus on the blood vessels diminishes uterine perfusion and called for the avoidance of the supine position to prevent supine hypertension.

Howard (1958) started a return in the upright physiologic position in 1954. He delivered 219 babies in a modified sitting position, and reported that the upright position, a sitting or squatting position, is practical, satisfactory from the mother's viewpoint, and should result in less intracranial damage to the child than has been encountered by the use of the various supine positions.

Pavlik (1984) asserted that there is now unequivocal evidence that the supine position for labour and birth has many disadvantages which can lead to problems such as a narrowing of the birth canal, compression of major blood vessels of the maternal mother, including the aorta, inferior vena cava, iliac arteries and urethras; loss of pelvic mobility; loss of the benefit of gravity; and diminished efficiency of contraction.

***BIOMECHANICAL ADVANTAGES OF THE UPRIGHT POSITION***

Mengert and Murphy (1933) carried out experiments on non-pregnant women and showed that intra-vaginal pressures, when bearing-down, decrease as the body approaches the supine position. Thus a woman in the sitting position is 30% more effective in bearing down than when she is in the horizontal, lateral or supine position.

Howard (1958), who applied the principles of physics, and the Newton's law of gravity on Mengert and Murphy's data, calculated that only 65% of the force needed for delivery in the horizontal position would be required in the sitting position. Further, Thomson (1988) reported an exploratory study that 30 minutes of pushing in the upright position is equal to 60 minutes of pushing on the horizontal position.

In the horizontal position, even the use of the forceps is faced with major mechanical and gravitational disadvantages. Howard (1958) reported an experiment where a spring-scale was used to measure the forces required for deliveries with Tucker McLean forceps. It was found that the average pull to extract the foetal's head was 35 pounds (15.9 kilograms), and the greatest was 74.8 pounds (35.7 kilograms). The direction of pull in general is in the horizontal and the baby's weight being vertical. The drawing below illustrates the problem, using Pythagorean formula.

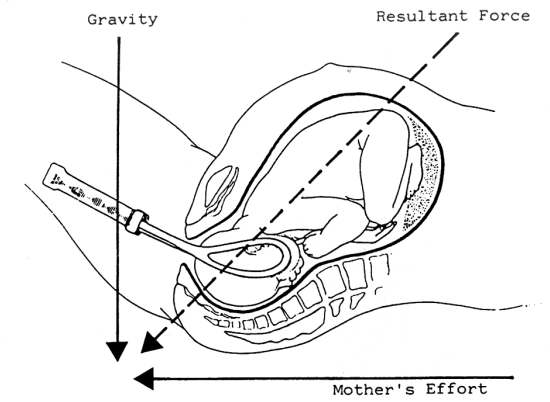


*Figure 1. Mechanical disadvantage of the horizontal position for childbirth and the use of forceps.*

It has been demonstrated that if the mother is upright, only 80% of the force needed in the horizontal position is required to deliver the baby. The average pull exerted in the upright posture is 28 pounds (12.7 kilograms), compared to 35 pounds (15.9 kilograms) for the horizontal position.

The drawing above shows the resultant forces created by the maternal and gravitational forces. If the mother is lying on her back during childbirth, she is pushing her baby out at right angles to the gravitational force, resulting in greater incidence of maternal tissue tearing, as the resultant force is directed at the perineum rather than the vagina sections. Considerably more effort is required as the mother attempts to push the baby uphill, against gravity (Dunn, 1976; Inch, 1985).

## DESIGN, DEVELOPMENT AND EVALUATION OF THE OBSTETRIC BODY-SUPPORT SYSTEM FOR UPRIGHT LABOUR AND CHILDBIRTH

A major goal in Ergodesign is to design childbirth equipment, systems and practices that promote optimum mother and foetal well-being, especially in clinical management that supports assists foetal descent, foetal oxygenation, takes advantage of gravity, biomechanically more efficient bearing-down, assists pelvic cavity expansion, minimises foetal injuries if forceps are used, prevents compression of the aorta and inferior vena cava, improves blood-gas scores, promotes umbilical artery and vain pO2, lowers pCO2, improves Apgar scores and time of 'first cry' etc. These factors form the key design criteria to be incorporated into the Obstetric Body Support System.

The functional quality of the obstetric system will depend primarily on the ergodesigner's ability to create the overall good fit between user and hardware in the human-equipment interface that is informed by the design criteria mentioned above. The range of uses and users is extensive and complex. To optimally accommodate these ranges, consideration of caregivers', mothers', and babies' needs, safety and functions are paramount. These have to be carefully researched and incorporated into the system during the design and development process. Perhaps more importantly, they have to be empirically evaluated in hospital settings, with evidence that is accepted by mothers, midwives, obstetricians, clinicians, and hospital health boards.

There is now unequivocal evidence that the horizontal position adopted in hospital for labour and birth is harmful to both mothers and babies. An ergonomist or a designer is professionally unqualified to be credibly involved in the clinical aspects of childbirth. However, an ergonomist's strength is in problem framing and problem solving to create opportunities and solutions through design and innovation. According to Dunn (1976) the less physiological supine position that fails to use gravity may also result in greater discomfort and pain, slower progress of labour, maternal antepartum and postpartum haemorrhage and foetal distress. An unergonomic posture taken during childbirth is considered to be one of the main causes for increased drug use, pain, maternal injuries, and Caesarean sections. No other animal species adopts such a disadvantaged position, lying on their back, during such an important and critical event, to give birth to their babies. It is beyond the scope of this paper to expand into the magnitude of other clinical problems that may be caused by the unergonomic posture adopted during labour and childbirth. The most important mission for this paper is to demonstrate how it is possible to apply ergodesign to create a birthing system that will ensure that the mother's enormous psychological, physiological, and biomechanical capabilities are relied upon to give birth spontaneously – without technological intervention.

## CASE STUDY: THE SEVEN PHASES OF ERGODESIGN

This case-study could be delineated into six phases in the system design and development. While in many areas the phases overlap, they nevertheless can be catagorised as follow:

1. Rapport building
2. Feasibility studies
3. Concept design
4. Mock-up and interim evaluation
5. Detail design and specification
6. Evaluation

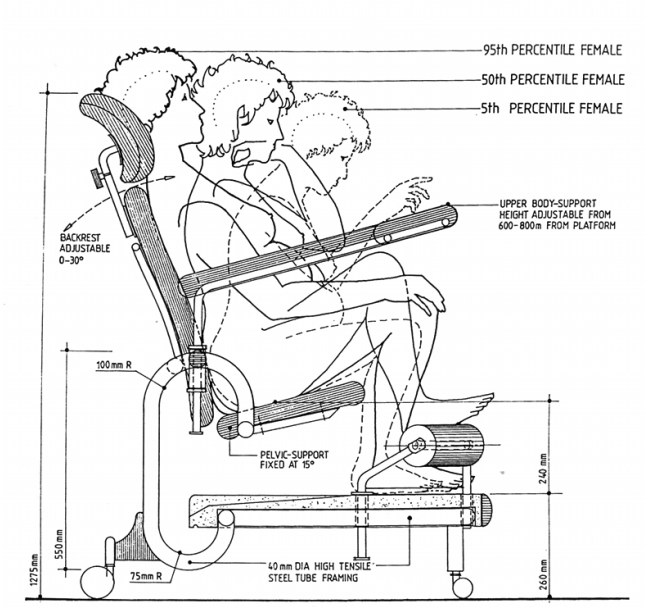


*Figure 2. Side elevation of the Maternal Body-Support System: The Active Birth Chair - designed by Leong Yap.*

The Obstetric Body-Support System, comprising of a "birth chair" and a caregiver's "seat-kneeler", were designed and tested in a comprehensive process, involving 19 participants from six different user-groups over a four-year period. Three user-groups comprised 4 independent midwives, 7 midwives from the Wellington Maternity Hospital and 3 expectant mothers in the Prenatal Evaluation. A consultant obstetrician, 2 midwives from the Kenepuru Maternity Hospital, and 2 postnatal mothers tested the system in the Postnatal Evaluation.

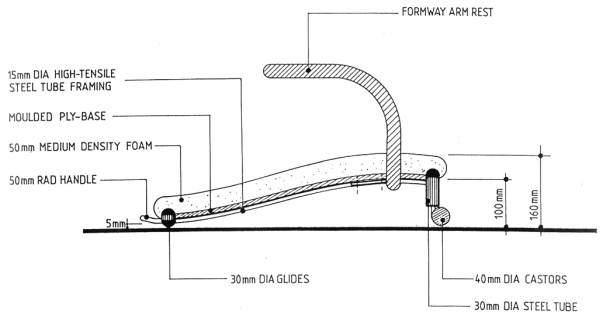


*Figure 3. Side view of the Caregiver's Body-Support System. The Delivery Seat-Kneeler - designed by Leong Yap.*

For ethical and clinical protocol reasons, the evaluations of all births were conducted by managers of the Maternity Units in the two hospitals, on behalf of the ergodesigner.

*Figure 4. Research & Design Process of Obstetric Body-Support System, and Prototype Development - designed by Leong Yap.*

Psychophysical assessments, or the subjective estimate methods, with both absolute and relative judgments, were used for the evaluations. The questionnaires were structured to evaluate predetermined areas of interest. All questions were constructed on seven-point "graphic rating scales". This was chosen to enable the accurate evaluation of fine psychophysical discrimination of sensations that were deemed important in labour and childbirth. From an administration perspective, graphic rating scales were also chosen because they are more interesting for the participants, simple to fill, and do not require the participant to bother with numbers (Chushman & Rosenberg, 1991; Guildford, 1954).

Four different sets of questionnaires were used for the evaluation. Two sets for testing the whole system, and two sets for testing the birth chair. The system questionnaires were used by birth attendances, one set for the prenatal test and another set for the postnatal test. The birth chair questionnaires were used by all participating mothers, one set used by prenatal mothers and another used by postnatal mothers. The system questionnaires, "Obstetric Body-Support System Evaluation" questionnaires, were designed to gather information on the function, usability and design features of the entire system for the delivery of a baby. The "Active Birth Chair Questionnaires" were designed to gather information on the ergonomics, perceptions, feelings and opinions of the mothers on the use of the Active Birth Chair for labour and childbirth.

## DESIGN OUTCOMES AND CONCLUSIONS

The results of the evaluations and tests showed that mothers and caregivers have received the Active Birth Chair, the Seat-Kneeler, and the entire system with a high level of acceptance as an option for childbirth. Besides providing ergonomic support for the mother, the system had been found to contribute to the psychological and physical well-being of the maternal mother by making her birthing experience more "active", "comfortable", "easy to push"' and "satisfying". These are element for a "Good Holistic Birth" – the current study has set out to provide. One woman, after a prolonged labour on the bed, "was saved from intervention with forceps" with a "good birth" on the Active Birth Chair. This statement, from the obstetrician who delivered the first baby on the System, is an important substantiation that supports the research hypothesis that the upright birth position, which takes advantage of gravity and the more effective biomechanical bearing-down power of the mother, is more natural and physiologic for childbirth. Of the 15 design features in the Active Birth Chair, and nine design features in the Sear-Kneeler that were tested, no major hazards that might disadvantage the birth process, or endanger mother and baby had been found. Only the seat angle of the Active Birth Chair was considered to be too great and required modification by some mothers and caregivers.

*Figure 5. Psychophysical assessment of Obstetric Body-Support System by midwives and obstetricians at Wellington Hospital.*

The key to this success is based on the following five areas. First, the use of ergodesign enabled the ergodesigner to apply an empirical approach to evidence-based design. Critical analysis of the

medical model had informed the design and evaluation of a system that revolutionised childbirth and the management of childbirth, by allowing the mother to labour in the upright posture, and reversing the delivery position of the caregivers from looking down at the mother's abdomen, to looking up at her perineum. descend from the birth canal with ease, naturally and physiologically. The new forward-facing position of the birth attendants enabled them to have better hand-eye coordination to deliver the baby more efficiently. Midwives and obstetricians are now able to see the baby being born in a more ergonomic position.

*Figure 6 &7. Psychophysical assessment of Obstetric Body-Support System by childbearing mother and midwives at Wellington Hospital, and briefing labour ward supervisor just before trial at Kinerpuru Maternity Hospital in Wellington.*

Second, mothers, midwives, obstetricians and management of the health boards were fully involved in all stages of the research, design and development, and evaluation process. Participants in the transdisciplinarly approach provided the ergodesigner with the insight of childbirth and all participants were active in the appraisal, decision-making and testing of the design concept, mock-ups and prototypes. Third, the judicious application of ergonomics that is guided with an evidence-based practice, together with innovative system design thinking, has produced a system that is beneficial to mother and baby. The system is functional, reliable, safe and delightful to use.

The fourth factor in the success of this project, were the increasing number of well-informed mothers, midwives and obstetricians who were cognizant of the concept of upright physiologic childbirth, and were committed to collaborate with the ergodesigner. Fifth, the use of ergodesign ensured the smooth flow of ergonomics theory into evidence-based design practice, thus reducing disciplinary barriers often encountered in system design and evaluation when ergonomics and design are used as separate disciplines. Despite the success, the number of participants used in the evaluations is considered too small for firm conclusions to be drawn from the results. Further positive test results are needed before the system could be put into general use.

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