# Driving posture assessment: a new approach

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**Abstract.** In this paper, a new theoretical model for driving posture assessment is proposed. Other than many models that focused on sitting (dis-)comfort evaluation, our model incorporated both sitting and driving activities such as steering and pedal control. By regarding both subjective and objective posture evaluation methods, we summarized several important findings from literature in this field and extracted three aspects for driving posture evaluation, i.e. accommodating various sitting strategies, reducing physical strain, and allowing optimum physical performance of drivers. Major impact factors were selected accordingly to determine the essential parameters for a more holistic evaluation process. These could be used for further development of digital human modeling software like RAMSIS. This new model would potentially allow a more effective and ergonomic occupant packaging.

**Keywords:** Driving Posture Assessment, Occupant Packaging, Digital Human Modeling, Biomechanics, RAMSIS.

## 1 Introduction

One crucial task in the occupant packaging process is to place a digital human model (DHM) in an ergonomic driving position to create a solid foundation for further cockpit development. Though, it is not easy to define an “ergonomic” driving posture since it incorporates both subjective and objective factors.

The major concern with using subjective preferred posture was that it could be influenced by many factors such as experimental setups, the test subjects or driving tasks [1–3]. Therefore, researchers developed various methods to objectify posture assessment. Nevertheless, a purely objective optimum posture would not always be accepted by drivers themselves [4]. It could presumedly overlook some important subjective factors of drivers.

Sitting strategy could be one of them. Many studies have shown that different drivers tend to have different postures which could be classified into various sitting strategies [5–8]. They are influenced by the characteristics of both vehicle interior and driver. For example, RAMSIS uses its Posture Model to take the influences of interior dimensions on postures into account. Nonetheless, within a Posture Model, RAMSIS has only one sitting strategy which is called Neutral Posture. Thus, there is potential of improvement to consider the variance in sitting strategy during posture assessment and, more importantly, the decisive factors of the various drivers.

Regarding the objective evaluation methods, many sitting (dis-)comfort models have been established to use objective parameters such as pressure distribution or muscle activation to predict discomfort [9, 10].

One widely used parameter is the joint angle. By measuring the joint angle to joint range of motion (ROM) ratio, passive muscle stretch can be evaluated. This has two major limitations though: first, muscle activation cannot be evaluated by using joint angle only. More biomechanical parameters like joint load are needed [11]. Second, a joint ROM has several impact factors which are often not accurately represented in DHM. In RAMSIS for example, the joint ROM are independent to each other. However, for those joints crossed by multi-joint muscles of which the finite muscle length could limit the range of movement of the involved joints [12], the ROM are not independent. Thus, to execute a proper biomechanical analysis, a DHM should have an appropriate physiological representation and corresponding parameters.

In recent years, more research about the optimum posture for driving has been done by using biomechanics regarding both physical strain and physical performance [13–15]. They introduced a new aspect to the driving posture assessment that not only focused on SITTING, but also considered DRIVING activities. This can be beneficial since optimizing driver's biomechanical condition would potentially increase driving safety.

The aim of this paper is to propose a new theoretical model that combines subjective and objective evaluation methods to assess driving posture. We analyzed several important works in this topic field and arrange the findings into three sections: sitting strategy, physical strain, and physical performance. In result, we extracted few key parameters and merged them into our model.

## 2 Analyses

### 2.1 Sitting strategy

A driving posture is a result of the interaction between driver and vehicle interior. Therefore, it is affected by the characteristics of both [3]. Studies using subjective evaluation methods to examine preferred posture will have the results that imply these influences.

For example, we visualized five preferred driving postures from four studies [2, 5, 7, 16], and compared them to RAMSIS Neutral Posture of the Posture Model "Car", as Fig. 1 illustrates. Each posture was reconstructed in RAMSIS by using the mean joint angles of each recommended joint angle range respectively, and torso reclination was set at 27° for all (same as the RAMSIS mannequin) for better comparability. Note that only [2] and [7] provided H30 values of their setups, while RAMSIS and [5] only documented vehicle types. [16] reported neither H30 nor vehicle type. [2] and [5] measured both sides of the body, the others provided only one side recommendation. Fig. 1 clearly demonstrates the impacts of the experimental setup on driving postures.

These posture variances could also be viewed as different sitting strategies under influences of interior dimensions, which confirms the finding of Park et al. [6] that H30 has a significant effect on lower body sitting strategy.

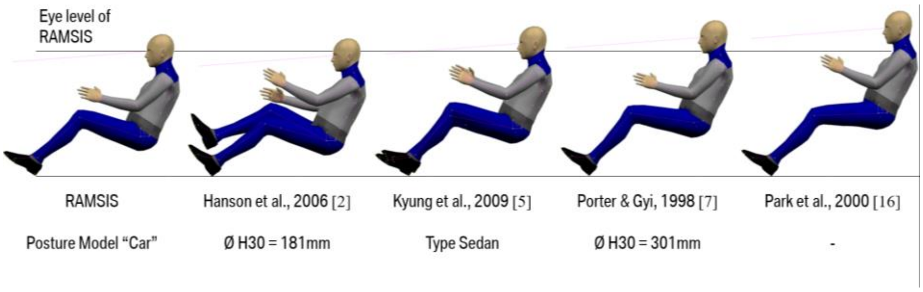


**Fig. 1.** Comparison between the RAMSIS Neutral Posture of the Posture Model "Car" and preferred driving postures from four studies [2, 5, 7, 16].

Furthermore, Kyung & Nussbaum [5] and Porter & Gyi [7] found that female drivers would have more flexed elbow and erect back, indicating that they might adjust the seat to sit more closer to the steering wheel and more upright than male drivers, as Fig. 2 shows. Similar results can be found in the study of Park et al. [6], showing that gender has a significant effect on the upper-body strategy. Therefore, even though RAMSIS Posture Models like "Car" or "Heavy Truck" in fact presented the H30 impact, other factors of driver like gender or body dimension should be considered.

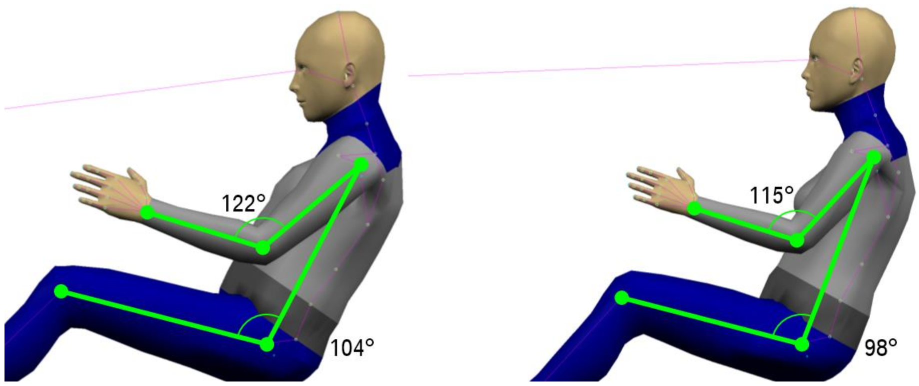


**Fig. 2** Visualization of preferred driving postures of a medium sized male (left) and a medium sized female (right) from the study of Porter & Gyi [7]. The male driver has a more reclined upper body posture while the female driver has a more upright posture.

More importantly, a sitting strategy can reflect the driver's prioritization of basic requirement for driving abilities. Wang & Bulle [8] found that, for most of the test drivers, the primary factor to adjust driving posture was pedal accessibility; for short and medium sized drivers, the second factor would be road visibility, while for taller drivers, it would be steering wheel accessibility. If engineers are not aware of such differences of requirements and solely use one sitting strategy like the Neutral Posture to assess all mannequins, faulty evaluation result could occur. This can be an issue particularly for the drivers with extreme body sizes which will reach the adjustment limits of seat and steering wheel more likely. Accommodating various sitting strategies would ensure a driving posture to retain in a reasonable range.

## 2.2 Physical strain

For drivers, physical strains like soft tissues compression, muscle stretch and muscle activation should be reduced to minimize physical discomfort and fatigue. They can be grouped into passive and active responses.

**Passive response**

*Soft tissue compression.* Compression of soft tissue such as nerves or blood vessels are often considered as a reason of discomfort [17]. It is often represented by measuring surface pressure distribution, which is a commonly used method for discomfort evaluation, and probably the most effective one [10]. Nevertheless, it can still be complex for ergonomic engineers to use this kind of information at an early stage of vehicle development, where driver seat is normally not yet completely developed. Though, engineers can qualitatively examine whether there is enough contact area between seat cushion and thighs, while also assure that the cushion front does not interfere too much during pedal operation.

*Muscle stretch.* An effective indicator of muscle stretches is the joint usage (joint angle to joint ROM ratio) since joint ROM is oftentimes limited by insufficient muscle length during stretching. Therefore, it is important to represent the ROM in DHM properly. An important effect that should not be neglected is multi-joint muscles, since there are many of them in the human body [12], especially in the lower body. NASA [18] also explained that “the movement range of a single joint is often drastically reduced by the movement of an adjacent joint” with multi-joint muscles due to their passive insufficiency, indicating that the ROM of these joints are not independent. For driving posture specifically, Porter & Gyi [7] reported that no subject in the study had chosen small trunk-thigh angle when the knees were more extended, since the hip flexion could be limited by the hamstrings, which are two-joints muscles. Thus, to evaluate passive muscle stretch more precisely, DHM should integrate a Joint Angle/Muscle Length function that includes the multi-joint muscle effect. In addition to this, many other impact factors like age and gender [19] should also be considered for better accuracy.

**Active response**

Since human driving operations are performed by muscles, muscle activation level (active muscle tension to max. isometric tension ratio) is a major factor to evaluate to prevent physical discomfort [11]. Other than passive muscle stretch, muscle activation level cannot be assessed solely by using joint usage without further biomechanical parameters.

One example is the lower leg muscle activation by accelerator control. If we only measure the joint usage, a dorsiflexion of the right ankle between 5° and 10° would have about 16% to 32% joint usage according to RAMSIS. This would be acceptable if the foot only rests on a surface without exerting force actively, which is not the case during accelerator operation. In a study we conducted in early 2020, 12 subjects sitting in a sedan configuration with H30 at 250mm, 70° knee flexion, and 5° foot dorsiflexion experienced on average moderate to strong discomfort on right lower leg during accelerator control. Our surface EMG results indicated that they contracted the tibialis anterior (TA) at a higher level more often. It can be assumed that within such a posture, the TA was first shortened by the foot dorsiflexion and would have to contract more often and intense to actively hold the foot in place. Therefore, it would lead to local discomfort more quickly than one with the foot in plantar flexion, where the TA was then passively stretched and no longer needed a high activation. Since plantarflexors are much larger than the TA, their activation level should also be much lower.

Thus, to evaluate muscle activation more accurately, a reasonable biomechanical representation of human muscular system and parameters such as joint load and muscle length should be considered.

Joint load changes with posture and therefore the muscle activation also changes. During steering for example, the shoulder of a more stretched arm would have to generate a greater torque than a more flexed elbow due to the increased length of the moment-arm. However, joint load alone cannot represent the muscle activation level, as Seitz et al. [11] discussed. Another essential parameter is the muscle length. According to the Force-Length characteristic [12], the max. isometric muscle contraction changes with muscle length, and the optimum is often at its resting length. For a given load, if the muscle is shortened or lengthened from its optimum length, the max. isometric muscle contraction decreases, therefore, the muscle activation level would increase as the muscle.

### 2.3 Physical Performance

In addition to a rational sitting strategy and lower physical strain, we suggest that an optimum posture should also allow drivers to achieve the optimum physical performance for primary driving tasks, which would benefit driving safety.

The muscles length is again a major parameter to consider. In addition to the Force-Length relation, the Force-Velocity relation [20] can be used to evaluate muscle contraction velocity. It described that, by concentric contraction, the higher the muscle load, the lower the contraction velocity. Therefore, an optimized posture for driving activities should also allow involved muscles to remain in their optimum length range as much as possible to assure the optimum muscle contraction velocity.

In the study of Schmidt et al. [15] for example, the steering velocity of the more stretched arm with an elbow angle at 145° was significantly lower than that of a more flexed elbow at 95°. In this case, it can be assumed that not only did the shoulders have to generate more torque to steer, but also that many muscles in the arms were lengthened beyond their optimum length and therefore activated at a higher level. Accordingly, the muscle contraction velocity would be lower, and the steering velocity could therefore be affected. However, this assumption needs to be examined by conducting more experiments, especially about lower extremities during pedal control, since not many studies have been found regarding this aspect.

## 3 Theoretical model

Based on the analyses above, the prime goal of this model is to provide a theoretical basis for a holistic yet practical driving posture assessment. As Fig. 3 illustrates, this three-level hierarchy is described as following:

First, sitting strategy: driving posture is influenced by characteristics of both vehicle interior and driver. It is important to understand that drivers have different prioritizations of requirements for driving operation, and accordingly, they tend to use different sitting strategies. Accommodating various sitting strategies would ensure that the most basic but crucial driving abilities of different drivers could be met, such as accessibility of pedals and steering wheel, or road visibility. This would be the foundation of a realistic posture assessment.

Second, physical strain: if the first level is fulfilled, physical strain should be reduced to a lower level. On the one hand, passive physical strains like local tissue compression or muscle stretch should be minimized, especially considering effects like multi-joint muscles; on the other hand, muscle activation level should be reduced to an essential level, which can only be assessed by introducing proper biomechanical parameters like joint load and muscle length.

Third, physical performance: if the second level is fulfilled, the optimum driving posture should allow a higher level of physical driving performance like faster or even more precise handling. In regard of Force-Length and Force-Velocity relations, engineers should determine whether a posture would deliver the optimum muscle condition to perform a certain driving task.

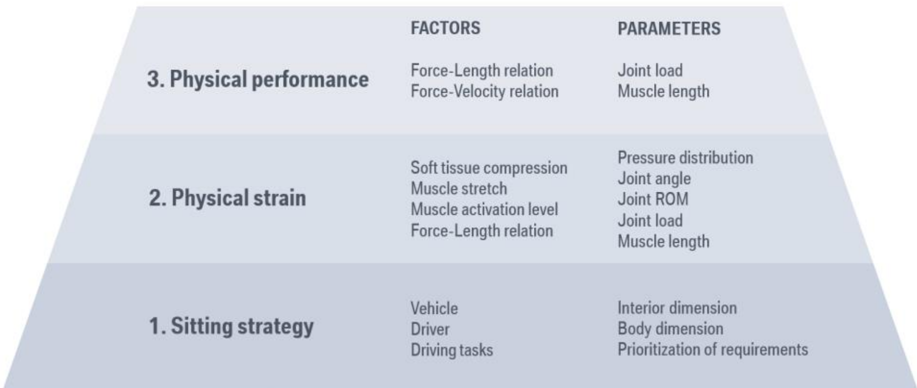


**Fig. 3.** Illustration of the proposed three-level model for driving posture assessment.

## 4 Summary

In this paper, a theoretical model for driving posture assessment is proposed. Unlike many previous (dis-)comfort models for sitting evaluation, this model incorporates both sitting and driving activities by regarding both subjective and objective factors. It also includes the latest perspective in this topic field that uses biomechanics to examine physical performance for primary driving tasks like steering and pedal control.

Nonetheless, further investigation and evaluation are needed. Thus, we will conduct an experiment on how lower body posture could affect both the physical strain and physical performance during pedal operations. Then, we will combine this result with the previous research about upper body posture. Ultimately, a dedicated tool for whole body driving posture assessment could be developed based on our model for more effective and ergonomic occupant packaging.

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