Data S1

Materials and methods

Motion simulation module of total hip arthroplasty

The motion from the THA model is shown in Fig. S1. The acetabular cup and the prosthetic stem fit based on this model. This simulation tool integrates all possible factors relative to the theoretical ROM. "There are eight parameters in total: acetabular size (D'), head size (D), general head-neck ratio (GR), stem abduction (SA), stem-neck (CCD) angle, acetabular anteversion (AA), acetabular inclination (AI), and femoral anteversion (FA)" (Ji *et al.*, 2010). The outer and inner diameters of the acetabular component are determined by D' and D, respectively; D and GR are used to determine the sizes of prosthetic femoral head and neck (Ji *et al.*, 2010). Here GR functions in the same way as the prosthetic oscillation angle θ (Yoshimine and Ginbayashi, 2002) and is actually determined by two factors: the neck and head diameters and the acetabular and neck design (Ji *et al.*, 2010). "When the cup surface is flat and non-elevated, the plane does not have the chamfer angle, and the neck is a cylinder, GR equals to the real head-neck ratio" (Ji *et al.*, 2010), as shown in Fig. S1. In the ordinary standing upright position, the femoral y-axis is assumed to be parallel to the Y-axis. "SA is the angle between the axis of the prosthetic stem and femoral y-axis corresponding to the anatomical femoral axis; CCD angle is the angle between the axes of the prosthetic stem and the prosthetic neck; FA, acetabular inclination and acetabular anteversion are three implantation parameters which describe the positioning of the hip prostheses; FA is the angle between the prosthetic femoral neck axis and coronal plane" (Ji *et al.*, 2010). Table S1 listed the range of values of these eight parameters.

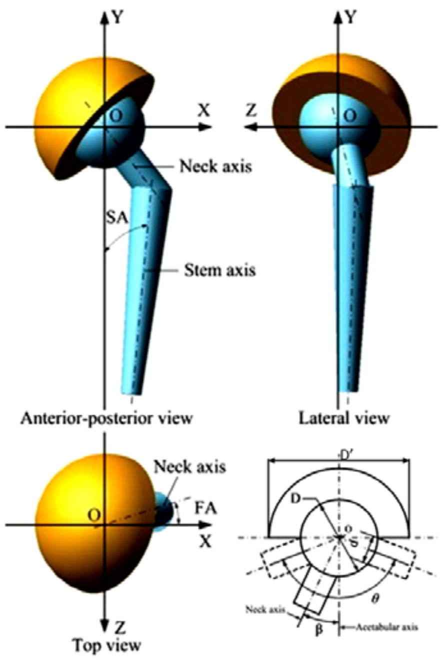

Fig. S1 Coordinate system and ROM of the THA model

This figure cited from figures 1 and 2 of WT-Ji's article (Ji *et al.*, 2010)

Table S1　Numerical scales of eight parameters in the simulation module of THA

Parameter name	Abbreviation	Numerical scale
Acetabular size (mm)	*D*′	Arbitrary
Head size (mm)	*D*	<*D*′
General head-neck ratio	GR	>1
Stem abduction (°)	SA	>0
Stem-neck angle (°)	CCD	90–180
Acetabular anteversion (°)	AA	−45–90
Acetabular inclination (°)	AI	0–90
Femoral anteversion (°)	FA	−45–90

Data quoted from Table 1 of WT-Ji's article (Ji *et al*., 2010)

"Based on the secondary development function of ADAMS/VIEW (MSC Software Corporation, Santa Ana, USA), the simulation module used integrating modeling, solving and visualization technology" (Ji *et al.*, 2010). The geometrical modeling of THA, kinematic simulation of six motions, initial position definition of implants, rotation angle measurement, impingement detection, and their parameterization and modularization are included in this module development (Ji *et al.*, 2010). The user interface of this motion simulation module of THA was shown in Fig. S2. "The left dialog box enables the user to achieve definition choice of acetabular orientation, parameter settings, modeling, precision definition, initial position definition and motion rendering, the model of THA and all rendering motions will be shown in real time", for more information on the simulation module please see WT-Ji's article (Ji *et al.*, 2010).

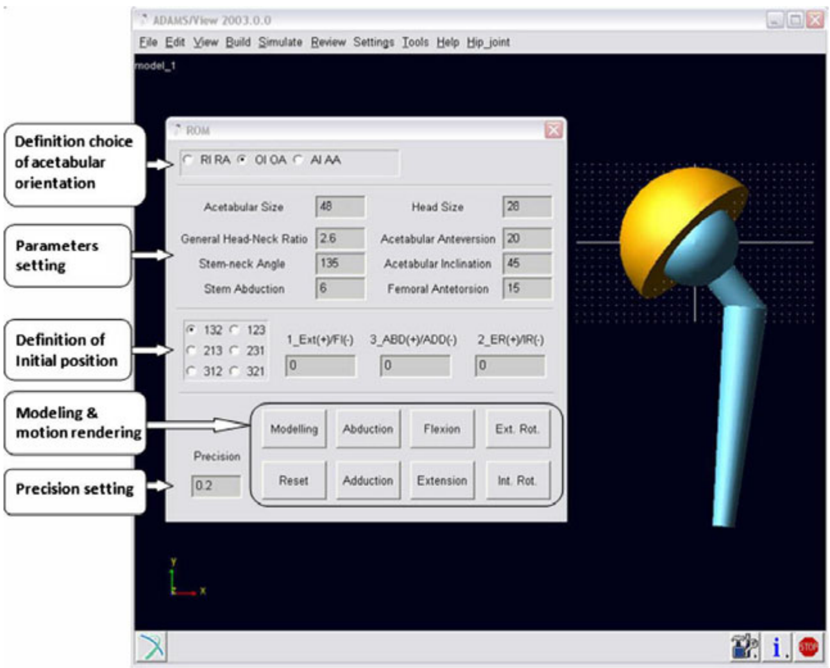

Fig. S2　Operation interface of the motion simulation module of THA

This figure cited from figure 3 of WT-Ji's article (Ji *et al.*, 2010)

This module of THA can simulate all rotation motions of implants (flexion/extension, abduction/adduction, internal and external rotation), and quantify the maximum rotation angle (Ji *et al.*, 2010). Because most daily living activities are combined motions, it is essential for the module of THA to have the capacity to simulate these motions until cup/neck impingement from any initial position, and not just the commonly used neutral standing position (Ji *et al.*, 2010).

Furthermore, we can accurately obtain the specific secure motion range of a hip implant with different design parameters, and learn and understand the impingement or dislocation risk of THA in various lower limbs activities. For the availability, functions and more detailed information about this module, please see the paper published previously in ClinBiomech (Ji *et al.*, 2010), for example, information about how to use the module to obtain the specific safe implant zone of the special hip implant.

Measurement of realistic kinematics of lower limb in ADLs

By using the optoelectronic 3D motion tracking system to capture the anthropometric kinematics, realistic kinematic data of lower limbs of general population had been measured. To secure the kinematic data, qualify and obtain the higher ROM, fifteen healthy males were selected to participate in the current study because adult males have good motion ability. The participants were students recruited from Shanghai Jiao Tong University, China; the average age was 23.8 years (Standard Deviation, SD 1.8), the average height was 171.5 mm (SD 5.3) and the average mass was 63.8 kg (SD 5.2). None of the participants had injury or pain history of the lower limbs, any type of lower extremity surgery, neuromuscular disease or balance problems. All of the participants had been measured for the kinematics of lower limbs in ADLs. This study was approved by the ethics committee of the Shanghai Jiao Tong University and all participants signed a consent form before participating.

Kinematic recordings were collected by the Optotrak® Certus™ 3020 three-dimensional active tracking system (Northern Digital Inc., Waterloo, Canada). This system has high precision; the 3D accuracy was 0.15 mm and the resolution was 0.01 mm. In order to gain more effective detection range, we used three Optotrak 3020 position sensors. The kinematic data were collected at a sampling rate of 95 Hz. For detailed descriptions of setting up the measurment experiment, please refer to the paper published previously (Zhou *et al.*, 2012).

The human lower limbs activity measurement contained six common ADLs, including normal walking, jogging, ascending and descending stairs, squatting, and kneeling. Part of the experimental process is shown in Fig. S3. Walking and jogging was performed on a treadmill (Qingdao Inray Co., Ltd.) and the kinematic results had good repeatability (Mills *et al.*, 2007). For ascending stairs, the stairs used in the measurement was made of aluminum alloy extrusion profiles and composite plate, and a handrail was not provided. The structure of the stairs conformed to the country's building standards, where the layer height was 160 mm, the pedal depth was 280 mm, and the pedal width was 900 mm. For squatting and kneeling, participants were required to complete the activities independently, and no instruments were provided. Participants repeated at least six effective trials for each activity to ensure the reliability of the kinematic data.

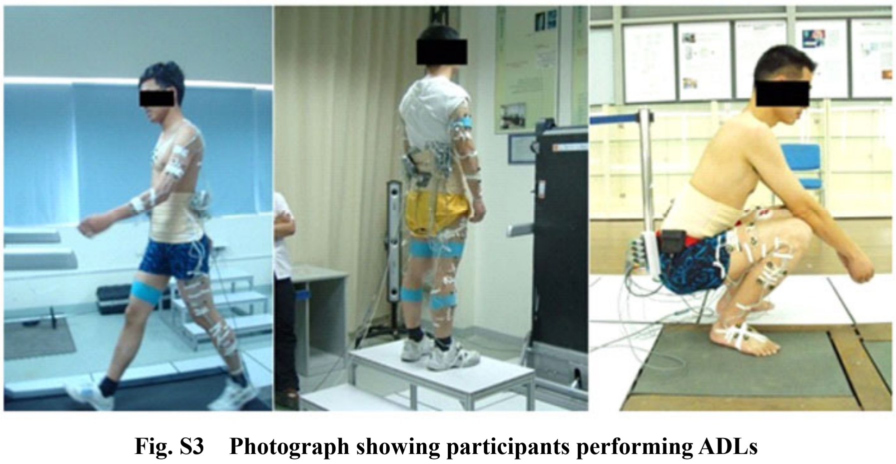

Fig. S3 Photograph showing participants performing ADLs

Data processing and statistical analysis

All of the kinematic results were relative to the dominant leg—the leg that participants use to kick a ball. The results were conducted using Visual-3D software version 3.91.2 (C-Motion Inc., Gaithersburg, MD), then saved in ASCII format and transferred to Excel and Graphpad version 5.00 (Prism5 for Windows). Finally, the kinematic values of the ankle, knee, and hip in three planes (sagittal, frontal, and transversal plane) in ADLs were obtained for statistical analysis.

In order to quantitatively examine kinematic data generated in ADLs, all mean peak joint angles and mean kinematic curves were produced. For each ADL, six trials for each participant were averaged and the mean peak joint angles of each participant were calculated. These individual data were then averaged to provide the mean peak value and SD. Correspondingly, the mean kinematic curves for each participant were used to create an ensemble mean kinematic curve.

References

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